This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

HN 1WRL Z

[illegible] Locomotive
[illegible]

KD 28412

Ellis

Practical Locomotive Running and Management

SECOND EDITION
THIRD THOUSAND

BY

W. GEO. KNIGHT

KD 28412

HARVARD
UNIVERSITY
LIBRARY
SEP 19 1946

Estate of
E. Raymond Ellis

COPYRIGHTED 1920
BY
W. GEO. KNIGHT
MEDFORD, MASS.

81

PREFACE TO SECOND EDITION

The same policy has been followed in the revision of the first edition to deal with principles of Locomotive Engineering in an elementary manner and an effort has been made to clarify subjects that are hard to understand by men who actually operate and maintain locomotives.

Many of the figures are reproductions of drawings or models I have used as an instructor to bring home to the reader the foundation of the subject; although radical departures from current literature, much success has been derived from their use.

The author desires to acknowledge with deep appreciation the assistance rendered by the following for use of cuts, literature and offering valuable suggestions:

The New York Air Brake Co.
The American Locomotive Co.
The Pilliod Co.
The G. M. Basford Co.
The Nathan Mfg. Co.
The Wm. Sellers Co.
The Chambers Valve Co.
The Locomotive Superheater Co.
The Southern Valve Gear Co.
The General Electric Co.
The Hancock Inspirator Co.
The Ashton Valve Co.
The Consolidated Safety Valve Co.
The Leslie Regulator Co.
The Mason Regulator Co.
The Franklin Railway Supply Co.
Mr. J. T. Anthony of the American Arch Co.

THE AUTHOR.

PUBLISHED BY THE AUTHOR
W. GEO. KNIGHT
36 CUSHING ST.
MEDFORD, MASS.

Price $4.00 Including Postage

CONTENTS

Page

Definitions of Technical Terms 9

Heat and Steam 13

Combustion 21

The Brick Arch 38

Locomotive Boilers 45

Superheat Locomotives 68

Locomotive Boiler Appliances 105

Locomotive Front End Appliances . . . 175

Locomotive Valve Gears 204

Locomotive Running 308

The Air Brake 413

A General Study of the Locomotive . . . 501

PRACTICAL LOMOCOTIVE RUNNING AND MANAGEMENT

DEFINITIONS

Water is a compound. It is made up of two constituents, HYDROGEN and OXYGEN, which, within all practical ranges of temperature, are gases. These gases are combined in the proportion by volume of two parts hydrogen and one part oxygen.

Hydrogen is symbolized by (H) and oxygen by (O). Water as H_2O., i. e., two parts of hydrogen to one part water.

Oxygen and hydrogen are elements. An Element is a substance in its most simplified form. It is one that cannot be broken up by any process into any substance other than itself. There are seventy-nine (79) known elements of which at least half are quite rare; but there are thousands of chemical compounds.

COAL is composed of carbon to a large extent. Carbon is an element and it is designated by the letter (C). In its purest state it is found as the diamond. Coal also contains compounds of hydrogen and carbon, which are spoken of as hydrocarbons, a common example (smoke). When coal is heated these hydrocarbons are driven off and the fixed carbon remains. A certrain percentage of absorbed moisture and other impurities occur in all coal.

AIR is a mechanical mixture of the elements oxygen and nitrogen (N) and contains in small quantities other elements and compounds. By volume there are twenty-one (21) parts of oxygen to seventy-nine (79) parts of nitrogen.

HEAT is a form of energy. When pure carbon is raised in temperature to the burning point in the presence of oxygen, a chemical action takes place and heat is generated. This is known as combustion. The product of complete combustion is a compound composed of one part carbon and two parts oxygen (CO_2).

THE UNIT OF HEAT is called the British Thermal Unit and is the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit.

One pound of pure carbon has a heat value of 14,650 B.T.U. That is, if the pound of carbon was completely burned to CO_2, it would give up 14,650 B.T.U. Or, if all of this heat could be transferred without loss to water it would raise 14,650 pounds of it one degree Fahrenheit.

A B.T.U. is approximately equivalent to 778 foot pounds of work. That is, if we could convert without loss one B.T.U. into work, it would lift a weight of 778 pounds through a distance of one foot. A pound of good coal contains on an average about 13,500 B.T.U. Therefore, $13{,}500 \times 778 = 10{,}503{,}000$ foot pounds.

HORSE POWER is the power required to raise a weight of 33,000 pounds through a distance of one foot in one minute. Horse power is therefore dependent on three factors, namely, force, distance and time.

BOILER HORSE POWER. A boiler cannot accomplish work in the same sense as an engine does. It has been found convenient, however, to rate the capacity of a boiler in this term. The unit of a boiler horse power is thirty pounds of water evaporated into dry steam per hour from feed water at 100 degrees F. and under a pressure of seventy pounds per square inch gauge.

The A.S.M.E. Committee on boiler tests (1884) accepted the same unit and defined it as equivalent to 34.5 pounds of water evaporated per hour from feed water at 212 degrees F. to steam at the same temperature.

ABSOLUTE PRESSURE—Boiler Pressure with the atmospheric pressure added to it, or in other words, 14.7 pounds added to the boiler pressure if measured at sea level.

INITIAL (beginning) PRESSURE—Pressure in the cylinder at the beginning of the stroke.

MEAN EFFECTIVE PRESSURE—The average of all the pressure acting on the piston during the stroke.

BACK PRESSURE—The pressure exerted against the piston while the engine is exhausting or the work necessary to get the steam out of the cylinders after doing its work.

WIRE DRAWING—Partially closing the throttle causing a reduction of steam pressure between the boiler and steam chest.

PISTON CLEARANCE—The distance between the cylinder head and piston at the center.

CLEARANCE VOLUME—The total space between the piston cylinder head and the volume of the steam port up to the valve seat when the crank pin is on its dead centre.

SATURATED STEAM—Steam having just enough heat in it to keep the water in a state of steam.

SUPERHEATED STEAM—Steam having an excess of heat (super) (above) or above heated steam, steam having more heat applied to it than it would absorb by boiling water to produce the desired pressure.

LATENT HEAT (hidden heat)—Heat that is not registered by the thermometer.

SENSIBLE HEAT—That which is shown by the thermometer.

DIRECT HEATING SURFACE—The surface of a locomotive boiler in direct contact with the flames (firebox sheets, combustion chambers, arch tubes).

INDIRECT HEATING SURFACE—The surface of the boiler not in direct contact with the flames (tubes, front tube sheet, etc.).

SUPERHEATING SURFACE—The Superheater.

HEAT AND STEAM

"Power," or energy, is used when it is transformed into work, and we see examples of this process every day around us,—in so many ways and so often that we do not stop to think about them. But let us stop and consider some of these ways:

A man in walking transforms the energy or power he gets from the food he eats into the work of moving his body, lifting weights, or doing other manual work.

A horse by virtue of the energy he gets in his feed is enabled to draw heavy loads.

Automobiles utilize the energy that is in gasoline, in traveling to and fro, carrying persons or otherwise doing work.

The locomotive of a steam train gets its energy from the coal it burns and does the enormous work required of it.

Some large construction work is going on, and heavy steel girders are raised from the ground to great heights by means of the hoisting engine and its cable. Here again energy in the coal is transformed into work.

Electric cars run in many directions, doing the work of transporting the public, and electrical energy, or "power," is required to do this work.

HEAT

When two bodies in the neighborhood of each other have unequal temperatures, there exists between them a transfer of heat from the hotter of the two to the cooler.

The tendency towards an equalization of temperatures is universal. Passage of heat takes place in three ways:

By radiation. Passing through the air without heating it.

By conduction. Passing through the metal.

By convection, or carriage from one place to another by heated currents.

All these characteristics of heat are present in the locomotive firebox.

The rate at which heat is transferred from the fire to the water has been subject to a great deal of investigation. While this subject is somewhat beyond the scope of this book, it is well to bear in mind that heat flows toward the cooler bodies in contact with it. Like steam, it flows toward the least resistance and the greater difference in temperatures the faster will be the flow of heat. An example will be found further on, showing the decreased evaporation with changes in temperature of the fire, which simply means the hotter the fire is the greater difference there will be between it and the water; hence, the greater flow of heat to the water.

This is why locomotive boilers are lagged to prevent the heat of the steam and water from flowing toward the cooler atmospheric temperature.

STEAM

Steam is a vapor derived by a continued application of heat to water. At atmospheric pressure of 14.7 pounds per square inch, water boils or changes its state, forming steam at 212 degrees Fahrenheit.

It will be observed by referring to Fig. No. 1, steam will be seen rising from the container, no matter how much heat is applied. The temperature of the water never rises above 212 degrees; the atmospheric pressure acting on the top of the water makes it necessary to apply 212 degrees of heat to secure steam.

Referring to Fig. 1, it will be observed a pressure of air is pumped into the tank on top of the water of 100 pounds. This pressure resists the boiling or steam formation until the temperature has reached 328 degrees Fahrenheit.

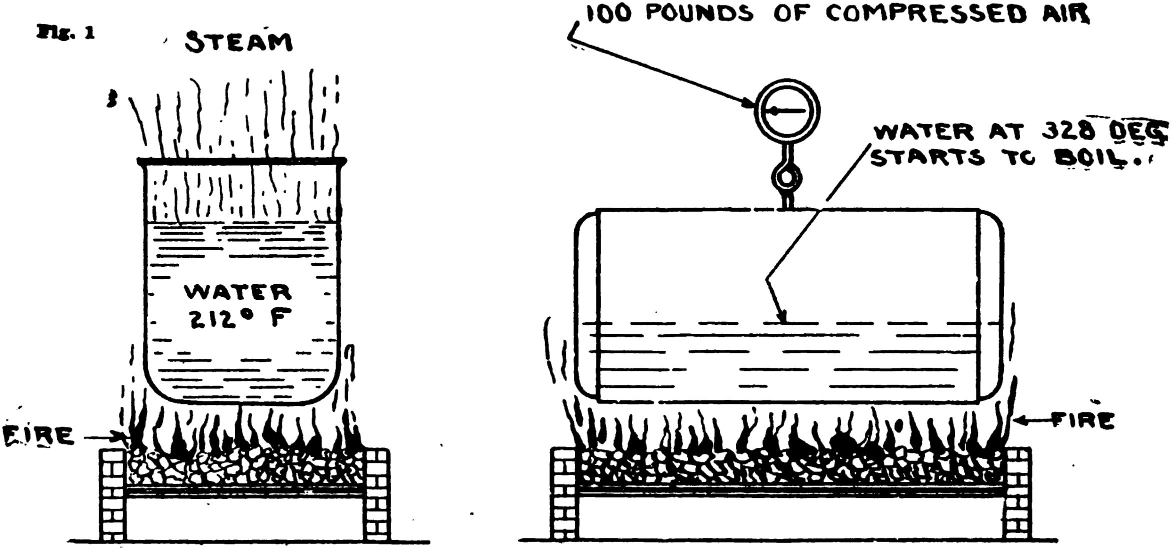
It follows, therefore, that pressure causes the water to be heated higher to obtain steam.

I have heard many men say the water in a locomotive boiler carrying 200 pounds of steam was 212 degrees, while the steam temperature is 387. Nothing could be more untrue. In order to form steam at this pressure, it is necessary to heat the water to 387 degrees.

The same thing is true when the atmospheric pressure is reduced; for example, try to prime an injector with hot water in the feed hose and pipe. The action of the injector in priming reduces the pressure on top of the water in the feed pipe and evaporates the water into steam, destroying the vacuum.

To prove further the air pressure on the water governs the temperature at which it will boil. Let us take for example the following atmospheric pressures at 8.20, 10.17 and 11.06 pounds per square inch. These

Fig. 1


STEAM
WATER 212° F
FIRE
100 POUNDS OF COMPRESSED AIR
WATER AT 328 DEG STARTS TO BOIL
FIRE

pressures will be found at high altitudes. Water boils at 184, 194, and 198, respectively.

One reason why an engine can be moved into the house after the fire is drawn is due to reducing the pressure on top of the water; when the throttle is opened causes the water in the boiler to evaporate into steam, supplying the space used by that entering the cylinders.

This can be proven further by taking an ordinary glass bottle filling it half full of water, placing it on a pivot so that it can be turned over (upside down). Place the bottle as shown in Figure No. 2, apply a gas jet at "A," having a thermometer inserted through the stopper at "B." Raise the temperature of the water in the bottle to 216 degrees, turn out the gas, invert the bottle cover, the end that the gas was in contact with, as shown in Figure 3, wilth a wet sponge and at once the water will begin to boil. Why? Because the cold water in the sponge condensed some of the steam on the surface. This reduced the pressure on top of the water and it boiled simply because the pressure on its surface was reduced. This example proves that pressure is the medium that determines evaporating temperature of water. We might reduce the pressure by opening a pet cock of some kind; in the foregoing example the result would be the same.

Since it requires a great increase in the temperature of water to produce steam at 200 pounds pressure, it would seem that the economy resulting was not in evidence.

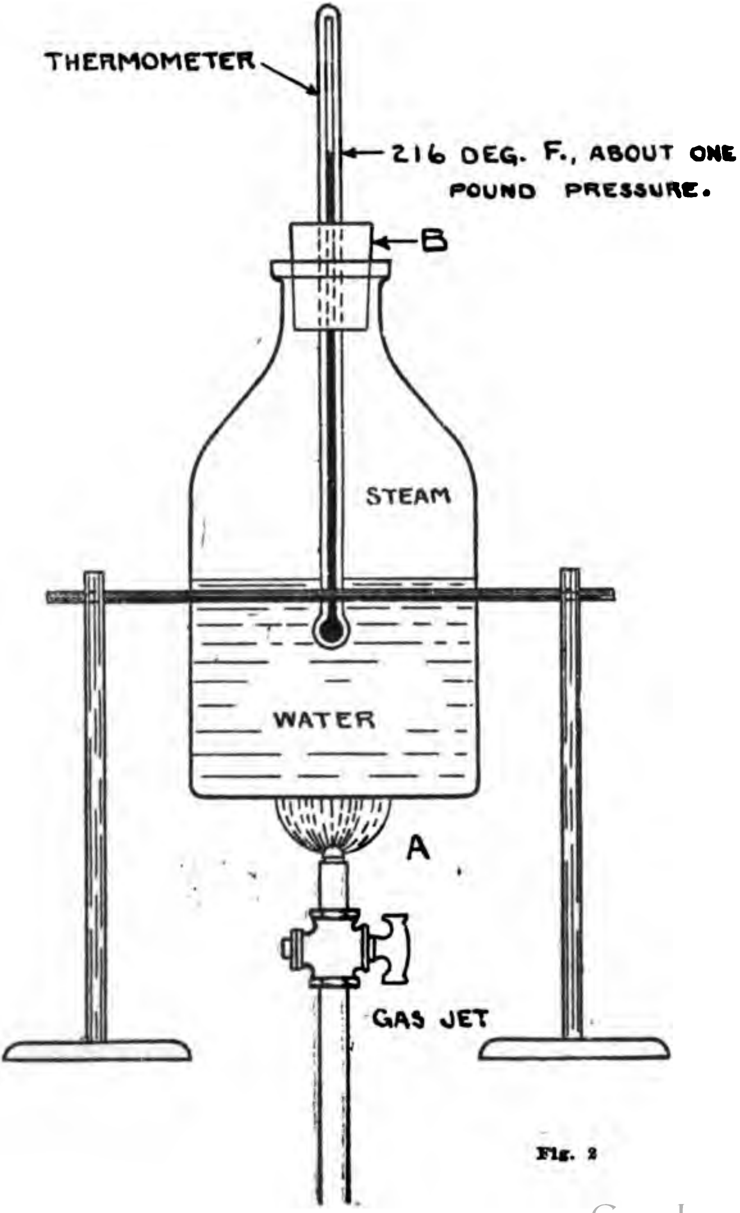

THERMOMETER
216 DEG. F., ABOUT ONE POUND PRESSURE.
B
STEAM
WATER
A
GAS JET

Fig. 2

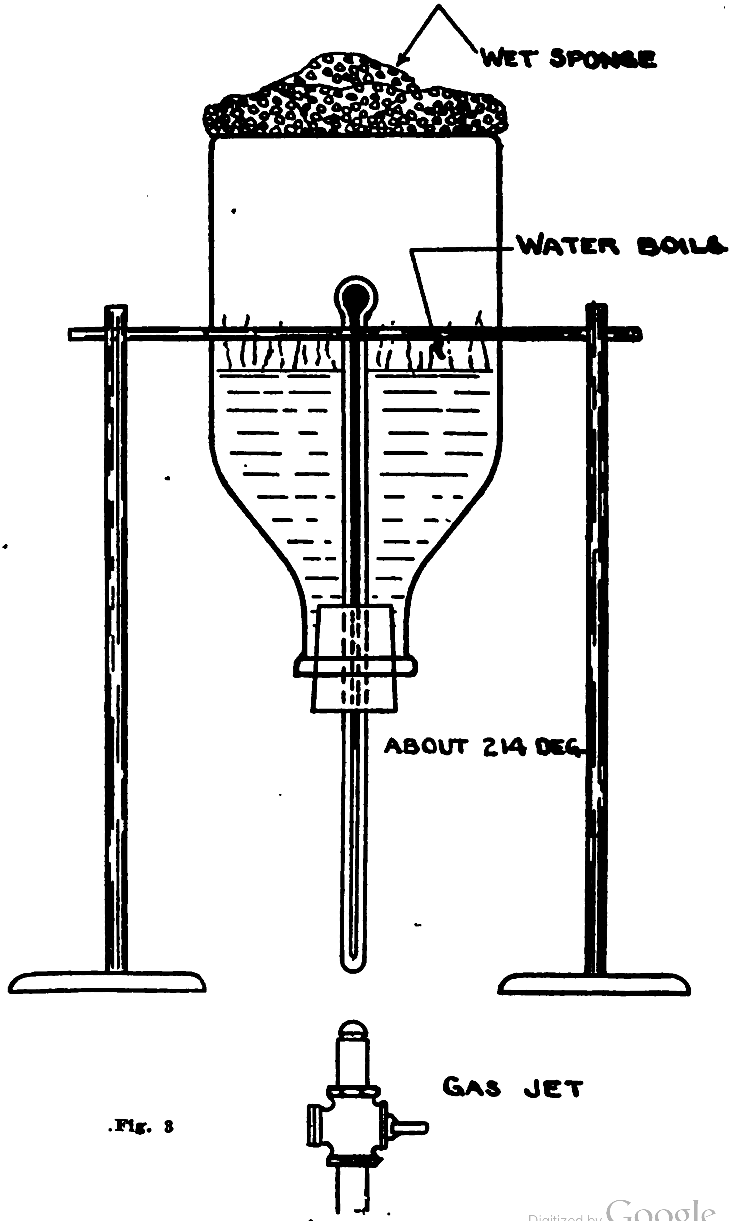


Fig. 3

However, steam at high pressure contains more heat and hence more energy.

It takes 1171.1 heat units to convert one pound of water into steam at atmospheric pressure 14.7 pounds per square inch and but 39 units more is required to increase the pressure to 105 pounds, and only 17.2 units additional to double the pressure to 225 pounds.

This is a very important point in connection with the economical use of steam in high pressure locomotives, since requiring but little additional heat units to raise the pressure as shown above, giving much increased energy to the steam, i. e., at high pressure much less steam will be admitted to the cylinder at the higher pressure to do a given amount of work than would be necessary at low pressure.

The advantage of high steam pressure in a locomotive is due to the expansive force it is able to exert against the piston. For example, steam at 180 pounds pressure is capable of expanding from eight to twenty-six times its original volume depending whether it exhausts into the atmosphere or a partial vacuum.

COMBUSTION

The B.T.U.—A. B.T.U. is known as a British Thermal Heat Unit. It is the amount of heat required to raise a pound of water one degree.

Chemical Symbols Used in Fuel Analysis:

Name	Symbol
Carbon monoxide	CO
Hydrocarbons	C_2H_6
Carbon Dioxide	CO_2
Sulphur Dioxide	SO_2
Oxygen	O
Nitrogen	N
Water Vapor	H_2O

When a pound of coal is burned to CO_2, it will give up about 10,000 to 14,500 B.T.U. However, when the air supply is restricted the coal is burned to C.O., yielding but 4,500 B.T.U.

Combustion may be defined as any rapid and chemical union of the oxygen of the air with a combustible material giving of heat and light. We must have fuel, air and high temperature to obtain combustion.

In stationary practice a device known as a CO_2 recorder is used to determine the quality of combustion in the firebox.

This device is operated by using caustic-potash, a chemical that absorbs carbon dioxide (CO_2) and is recorded by a gas bell or similar method recording it on a drum.

Samples of the escaping gases from the stack are taken for use in this instrument.

Economical firing generally shows a high percentage of carbon dioxide CO_2 generally running to 13 per cent. when the work is skilfully done.

The C.O. carbon monoxide should be as low as possible.

G. R. Henderson, in his locomotive operation, reports a test where a fireman left to his own judgment showed a CO_2 of about 5 per cent. while another trip with frequent shaking of the grates and light firing gave an average of 12.43 CO_2 and no CO.

MODERN IDEAS OF COMBUSTION

Bituminous coal consists principally of fixed carbon which burns on the grate with little or no flame and volatile matter which burns above the fuel bed with a long flame.

In order to approximate perfect combustion in the firebox of our modern, high-powered locomotive, with ordinary firing, it is essential that the following provisions be made:

A firebrick baffle to insure an intimate mixture of the volatile matter and air.

Flame-way or combustion space sufficient to allow all gases to be completely burned before reaching the back flue sheet.

In an ordinary locomotive firebox, all the air is supplied through the grate. As this air comes in contact with the glowing coals of carbon at the bottom of the fuel bed it gives up its oxygen, two parts of which readily unite with one part of carbon to form carbon dioxide.

The carbon dioxide thus formed passes on up through the fuel bed, and, unless accompanied by an excess of air, on coming in contact with the glowing coal at the top, it gives up part of its oxygen and is reduced to carbon monoxide.

When this carbon monoxide is brought in contact with oxygen or air which is heated to a sufficiently high temperature, it will be completely burned to carbon dioxide; otherwise, it may pass off unburned at a loss of about 10,000 heat units per pound of carbon, since carbon burned to carbon dioxide generates 14,650 heat units, while only about 4,430 heat units are produced when carbon is incompletely burned to carbon monoxide.

Bituminous coal contains from 25 to 50 per cent. volatile matter which, being rich in hydrogen has a very high heat value, generating from 12,000 to 21,000 heat units per pound of volatile. These volatile hydro-carbons are driven off when green coal is thrown on the fire, and if supplied with a sufficient quantity of heated air (or oxygen) will readily ignite.

If there is no excess air above the fuel bed, they pass off unburned, producing smoke, and leaving behind a deposit of soot in the firebox and tubes.

If there is partial supply of air, the hydrogen, having greater affinity for oxygen than the carbon, takes up the available oxygen from the air, forming steam, while the carbon is set free and either passes off in fine particles as smoke and soot, or combines with an insufficient quantity of oxygen to form carbon monoxide.

This shows the vital necessity for air above the fire, air being the medium through which oxygen is supplied; but the presence of air alone is not sufficient, for flue gas analyses often show incomplete combustion with large excess of oxygen.

When air at atmospheric temperature is admitted into the firebox, it has to be heated up to the igniting point before its oxygen is available for combustion, and if it enters in a large shaft, as through an open fire door, it is possible for it to flash through the firebox and into the flues before the igniting temperature is reached, in which case it hinders rather than aids combustion, and at the same time endangers the flues.

It is important that the air be heated, as the combustible gases will not combine with oxygen below about 1,100 degrees F.

It is also necessary to have an intimate mixture of the volatile matter and the air in order that every particle of carbon and hydrogen contained in the former may come in contact with the required amount of oxygen contained in the latter. In no other way can perfect combustion be obtained, yet this is a point that has been largely neglected.

It is very apparent that the flame-way or combustion chamber space should be long enough to give the gases time to mix and burn completely before striking the flue sheet, for the flames are extinguished on entering the small fire tubes and combustion ceases.

The amount of air needed above the fuel bed depends upon the composition and per cent. of volatile in the coal, the rate of combustion, the efficiency of the gas-mixing devices and the volume of the firebox and combustion chamber, and varies from 25 to 50 per cent. of the total air supply.

COAL

The composition of bituminous coal is about

50% Fixed carbon
40% Gaseous matter
10% Ash

The proper burning of coal is accomplished by bringing the oxygen of the air into contact with the combustible elements under at least 1,800 degrees of temperature. In the calorimeter, a device for measuring the heat in fuel, we get the total heat from coal by using oxygen under pressure and a perfect mixture ensues, giving the desired chemical combination. In the firebox good combustion is accomplished in the following manner:

The fixed or free carbon left in the form of coke, when the volatile matter has been driven off, burns as solid matter, the carbon combining with oxygen in the ratio of one part of carbon to two of oxygen, forming carbon dioxide (CO_2).

The volatile matter or hydrocarbons must first pass into a gaseous state and mix thoroughly with hot air forming CO_2, and hydrogen which combines with oxygen and forms water in the condition of steam due to the high temperature.

WETTING COAL

Wetting coal too much before firing is a bad practice, because the water used in wetting it must be evaporated in the firebox before the coal can burn. As it requires about 1,000 heat units to evaporate one pound of water, and as this heat is absorbed from the furnace and wasted, it can be seen that a large amount of heat is lost in evaporating the water from the coal. Throwing wet coal into a firebox also chills the fire, and is one cause of making smoke. Sometimes, however, in firing, when the engine is working hard, it is necessary to wet the coal to prevent the draft drawing it out before burned. It is also necessary to wet coal on the tender to keep the dust down.

The general conditions that tend to cause smoke are, too low temperature in the firebox, firing too much coal in one charge, not admitting enough air to the firebox, allowing holes in the fire which admit a large quantity of cold air at one point, and not securing a mixture of the air with the combustible matter being given off from the coal and having banks in the fire.

AIR REQUIREMENTS

One pound of air takes up about 13 cubic feet. Of this, about 2½ cubic feet is oxygen, or 4½ pounds of air to one of oxygen. Generally it is necessary to estimate 20 pounds of air to burn one pound of coal.

The amount of air entering an ashpan every minute, having an opening of 14% of the grate area, the usual minimum for modern engines assuming a grate area of 52 square feet and a draft pressure of ten inches in water is roughly 22,500 cubic feet.

This is generally insufficient to properly burn the fuel at the rate sufficient to hold the proper steam pressure.

HANDLING ENGINE ON ROAD

Firing on the road to obtain the best results in steam making and fuel economy.

Before starting out the fireman should see that the grates are free from clinker and ash and the grates work properly; that there is sufficient fire in the firebox and burning brightly, and the ashpan clean.

Before leaving the initial station the engineer should be sure and have the boiler well filled with water. This will allow the fireman to properly prepare his fire to hold the desired steam pressure for the trip.

The best method of firing is to keep as nearly as possible a constant supply of fuel entering the firebox consistent with the work the engine is doing. This, of course, cannot be done with hand firing, but it can, however, be accomplished efficiently by use of good judgment and by co-operation of the engineer.

As the engineman is in charge of the locomotive, his instructions should be followed, and both he and the fireman should work together to bring about the desired results. The best fireman cannot make a good showing with an engineman who does not co-operate with him in the proper handling of the injector, throttle and reverse lever. The fireman is not alone responsible for the saving in coal, as a great deal depends on the engineman in his proper operation of the locomotive, and the latter should give instructions and suggestions to the fireman, based on his experience to bring about the best results.

When applying fuel in building up the fire, preparatory to starting, the blower should be used, to create the necessary draft, and the fire door should not be entirely closed between the shovelfuls of coal, but in all cases should be placed on or against the latch until the gases have been consumed.

Fire as light and level as possible consistent with the steam requirements, scattering the coal over parts where the bed is thinnest and the fire brightest, in order to prevent it from becoming dead in spots. Large quantities of coal placed in the fire box at one time cool down the fire, cause smoke and waste of coal; small quantities at regular intervals will keep the fire bright, reduce smoke and take less coal to keep up steam pressure, resulting in a reduction in the work of firing.

Smoke represents a very small loss of heat from the coal. The weight of the carbon particles in a very dense smoke may be about 1 per cent. of the weight of the coal fired; but smoke represents incomplete combustion, and the conditions which prevent the complete combustion of these carbon particles would also prevent the complete combustion of some of the invisible gases of high heating values. The loss by not burning these gases is very large.

IMPORTANCE OF HIGH TEMPERATURE

Increasing the firebox temperature from 2,040 degrees to 2,540 degrees doubles the amount of heat radiated from each square foot of radiating surface, and practically doubles the evaporation from the firebox heating surfaces.

This shows the vital importance of high temperatures, both in fuel bed and flames, and shows effects that result from bank firing, or the placing of a lot of green coal in the firebox at one time. In order to get the maximum evaporation it is necessary that the fuel bed be kept at a white-hot temperature all over. The bank of green coal reduces the effective heating surface, reduces the temperature of the firebox, and evaporation.

The grates should be shaken only when necessary to clear the fire of ash and clinker in order to admit sufficient air for proper combustion, and in such a manner as to avoid the loss of good fire.

The grates should never be shaken when the engineer is starting the train. This results in a great loss of fuel and is liable to fill the front end or smokebox.

The engineer should guard against slipping the drivers, since the heavy exhaust will tear holes in the fire or turn it over, often called chowdering. This also may cause a steam failure by filling the front end and plugging the smokebox netting.

The firebox door should be kept closed until the reverse lever is hooked up, otherwise great volumes of cold air will be drawn into the firebox, resulting in a lower temperature and loss of steam pressure.

There should be enough coal in firebox before starting to avoid this.

Do not throw on the fire more coal at one time than is absolutesly necessary. Two or three shovelsful at one firing is enough, and generally one shovelful will be enough with careful firing. By putting a large amount of coal in firebox at one time, a good deal of the heat in the coal is wasted, as the supply of air needed cannot mix with the coal fast enough to burn it properly.

Always try to keep down smoke as much as possible. When steam is about to be shut off, open door a little just before throttle is closed and put on the blower a little.

When using steam, smoke can be prevented by keeping a white heat, firing a little at a time and holding door open about an inch for a few seconds after firing.

Do not allow steam to blow off if it can possibly be avoided. Steam blowing off means a waste of coal, water and labor. It can always be prevented while using steam by watching the gauge closely and opening door on the latch before pop valve raises. Try to keep the fire so that the steam pressure will vary as little as possible. By doing so the engine will use less coal and there will be less strain on the boiler and firebox, owing to the temperature being even.

Always carry as light a fire as possible, as by doing so much heat can be obtained from the coal than with a heavy fire. It takes a certain amount of air to get out of a quantity of coal all the heat. If you carry a heavier fire than is necessary, it will be a much harder matter to get sufficient air through the fire to enable it to mix thoroughly with the fuel and the gases.

Be careful to keep fire bright all over and free from holes, especially next the firebox sheets. That part of the fire nearest flue sheet should always be carefully watched, as cold air coming up through grates at that point will do more to cause steam to fall than any other.

Always break up lumps of coal to about the size of half a brick. By so doing you will expose a greater amount of surface of the coal to the action of the fire.

Wood split up fine burns better than large pieces; same is true with coal broken up about the size of a half a brick.

Often an engine will steam freely when large volumes of black smoke are emitted from the stack; many engineers and firemen claim it is necessary to have black smoke in order to have the engine steam well. The following situation generally exists: The coal fired contains considerable hydrogen gas. This finds its way into the firebox in the fuel as fired. Then hydrogen unites with the oxygen, but does not unite partially as it does with carbon; in other words, the hydrogen will use up the oxygen that the free carbon should have.

The reason why the engine steams is on account of the high heating value of hydrogen over carbon, having a relative heat value of 62,000 B.T.U. per pound for the hydrogen, and 14,650 for the carbon, and while we are producing heat from the hydrogen we are at a double loss by wasting the available combustible ingredients of the free carbon. It will be seen that heavy firing and black smoke are caused directly by using the small amount of hydrogen for steam, making instead of light and frequent firing getting the heat from both the hydrogen and free carbon.

DRUMMING

Often after cleaning fires or when the fire is very thin, a strong drumming noise will be heard. This is caused by the hydrogen in the fuel uniting with oxygen of the air, forming a gas known as oxy-hydrogen, having an explosive character.

The vibration caused by their explosions is very annoying and can be remedied by opening the firebox door a little and covering the thin spot with fresh coal.

ASH AND HONEYCOMBING

The "clinkering" and "honeycombing" of ash is one of the worst troubles to be contended with in the combustion of coal, and its formation may be either chemical or by fusion (melting).

Honeycombing or plastering, as it is sometimes called, is rather hard to remove from the firebox sheets. However, when allowed to slightly cool, it often can be removed by striking it lightly with the tee bar or scraper. Under this treatment it will often drop off in large quantities.

Care should always be exercised to prevent injuring the tube sheet and tubes.

ADVANTAGE OF LARGE GRATE AREA

Increasing the grate area increases the area of the fuel bed radiating surfaces, and increasing the firebox volume or combustion chambter space increases the flame-radiating surfaces. Increasing the grate area also means low rates of combustion, more uniform air supply, lighter fire, reduction in losses due to unburned fuel, an increase in the percentage of heat liberated and an increase in firebox efficiency, both as a furnace, or heat-liberator, and as a heat-absorber.

HOW FUEL MAY BE WASTED

Leaks or steam or hot water as at the mudring or of steam at the piston rod or valve stem packing mean the escape of heat and its complete loss.

Steam leaks into the firebox, or the superheater header or from the steam pipes mean direct loss of heat and probably a greater loss due to the poor conditions which such leaks bring about in connection with engine performance. Front end air leaks mean a coal loss, and blows past the engine pistons and valves greatly increase the amount of steam required and consequently the amount of coal which must be burned. Considerable coal may be wasted through safety valves. Forty or fifty pounds of coal per minute may be required to furnish steam to discharging safety valves.

In order to show the loss of fuel that may result from popping or blowing from safety valves, take for example, one 3-inch safety valve of a common make used on American railroads, with 200 pounds of steam on the boiler.

Here we find the safety valve discharging 147 pounds of steam per minute. The coal required to evaporate the above quantity of steam from water, figured at 7 pounds of water evaporated to one pound of coal fired, would show a loss of 21 pounds of coal per minute. Of course, if two are blowing, twice this amount is wasted. Since one pound of steam is the same as one pound of water, that is, one pound of water weighs the same as one pound of steam, we find that 147 pounds of water will also be wasted.

The location of block signals at difficult starting places often causes a large loss of fuel each year, especially when many heavy freight trains have to be stopped and started each day.

Much fuel is wasted by freight trains dragging brakes. It is not uncommon to see two or three cars in freight trains with brakes sticking slightly. Methods of preventing this will be taken up further on.

Air leaks in brake equipment is responsible for large fuel wastes. More complete discussion will be found in the air brake chapters.

Deadheading empty passenger cars on fast trains. It requires 15% more power to haul a car on a 40-mile-per-hour schedule than on a 20-mile-per-hour schedule.

Unreasonable speed restrictions or keeping speed restricting signals up after the reason for their display no longer exists, making it obligatory to reduce the schedule of the train unnecessarily. Poorly plotted train schedules. Much can be done in evening up running time so the engineer will not have to work the engine unreasonably hard over some portions of the division and have to kill time over others.

Using engines of excessive tractive power and weight on small trains. Much fuel can be saved by covering the stack while the engine is in the house, or set off, but the ashpan and firebox door must be constructed so they can be closed tightly, otherwise the cab will be filled with smoke and soot, making it disagreeable for the terminal forces.

Taking advantages of the physical characteristics of the road. The engineer should start the train slowly. It is interesting to watch engineers starting their trains from an initial station. Some will start slipping and tearing, while others will start slowly and gradually, bringing their trains up to schedule in an even and smooth manner, adding to the economy in fuel and lessening the labor of the fireman.

The engineer should take advantage of drifting his train as much as possible, remembering the fuel dissipated through the medium of brake applications, amounts to a material sum of money in a year. He should watch his schedule between stopping stations and see how far back it is possible to shut off steam consistently and reduce the speed through the natural resistance of the train, making the final stop with as little use of the brake as possible.

The fireman should at the same time regulate his fire so to prevent the safety valves blowing off and wasting the fuel that would be saved by the engineer handling his train in this way.

The treatment of locomotives at terminals, aside from repairs is important. When fires are cleaned the men should be taught to waste as little live fire as possible to the ashpit; blower must not be used harder than is necessary to keep the smoke and gas out of the men's faces and the pump should be shut off to keep the ashes and dust out of the air end and also to save the flues from cold air, which the pump exhaust will draw through them. If the engine is to stand in the house for a period of 36 hours or more it will, generally, be cheaper to dump the fire on its arrival than to hold under steam. If engines are kept under steam, however, the fires should be bright and alive next the tube sheet but with the back end pushed ahead and the back section of grates bare. With this method the fire doors may be kept shut, not allowing smoke to fill the cab, and the engines will stand for a long time without attention, never gaining steam enough to open the pop but holding plenty to work the injectors, move the engine at short notice or for any other practical purpose. Another good point of this method of holding fires is that, when it is being prepared for service, the back half is practically clean, as coked coal from the front of the box is merely pulled back to cover the grates which have been bare. Fire building is a point where saving can often be realized if a careful analysis of the situation is made. Flue blowing must be followed up and pains taken to see that the work is done properly. Tanks should not be overloaded at coal chutes.

Reducing the time the locomotive is held on sidings and terminals will help to save fuel.

THE BRICK ARCH

One of the necessary devices to be applied to a locomotive boiler in addition to the superheater is the brick arch.

The old style brick arch is set on lugs known as arch lugs attached to the side sheets. See Fig. 10.

The method used in setting arches in fireboxes of the larger type boilers having the firebox on top of the locomotive frame is by the use of the arch bar tube sometimes called water tubes, water bars, etc. The arches are made sectional and applied in such a way as will be observed in figures following.

The purposes of the brick arch, the great benefit of which is realized by every engineer and fireman, are:

First, to increase the path of the flame before entering the tubes or flues and thus prevent extinguishing it. Careful tests in this matter have shown that the flame of ordinary coal of average volatile substance enters the small tubes about three inches before it is smothered. After the brick arch is applied the flame must pass back and over the arch before it can get into the tubes. The value of this statement can be realized by placing a shovelful of coal on a bright fire and watching the length of the flame and distance which it will travel. At the same time the gases or flames are passing back and over the arch there is a mixture of air uniting with them admitted through the firebox door; under these circumstances the top of the arch forms a combustion chamber resulting in much nearer complete combustion.

Second, it is well understood generally in order to have proper combustion we should have a high temperature in the firebox. There firebox sheets rarely exceed a temperature of 420, therefore it will be seen that there will be a great cooling effect on gases coming in contact with those surfaces. The brick arch will not only provide means for maintaining a higher temperature in the firebox but will keep it more uniform and thus give greater life to the boiler.

Third, the back portion of the firebox is made more efficient by passing the gases in that direction, resulting in an increased evaporation by the firebox sheets. Not until the last few years has firebox or direct heating surface value over that of flue heating surface been fully realized. The above relation is a ratio of 7 to 1 about, i. e., 1 square foot of firebox heating surface is as good as about 7 square feet of flue heating surface. Arches are generally set to give a small clearance between the arch and tube sheet, although some railroads have set them against the flue sheet.

The disadvantage claimed against the latter location that there is greater liability for the top of the arch to become covered with cinders and fuel in such a way to cover a large portion of the tubes and render them valueless.

The firing should be done with care to avoid plugging or filling up between the grates and arch with green coal as this will practically render it useless, cut out the effectiveness of a large portion of the grate surface and generally low steam pressure will be the result.

The gas produced by the overage locomotive fuel is about 1,100 cubic feet per pound when placed on a good bright fire.

The arch increases the furnace efficiency by baffling, holding back and burning much of the coal dust and fine particles of coal that would otherwise escape as smoke or cinders; and by baffling and mixing the rich hydrocarbon gases with the oxygen that is present, and compelling them to burn before they escape into the flues. This increase in combustion and furnace efficiency is always followed by an increase in overall boiler efficiency.

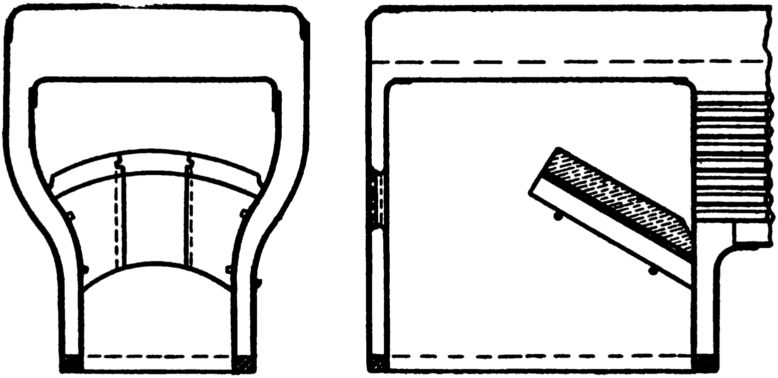


Fig. No. 10

This arch was composed of three bricks, the outer bricks being supported by studs in the firebox side sheets; the centre brick acting as a keystone to hold the arch in place.

Without the Arch a needless waste of from 10 to 20 per cent. of the coal fired would take place, resulting in a decrease in capacity and efficiency of the locomotive.

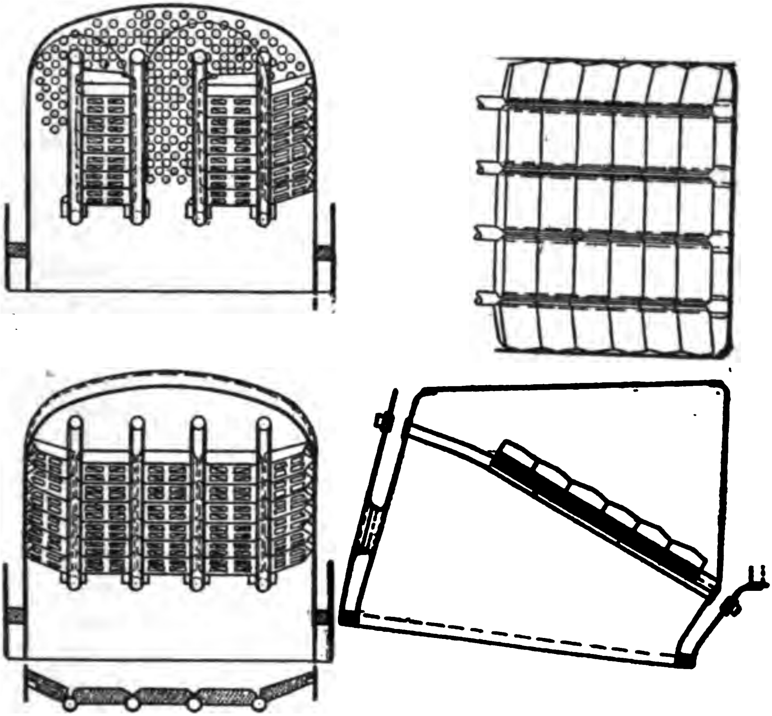


Fig. No. 15

The Modern Security Sectional Arch, in which the brick fit snugly upon and in between the arch tubes. These sections can be easily removed and replaced when access to tubes and staybolts is necessary. Note recesses in bottom of brick.

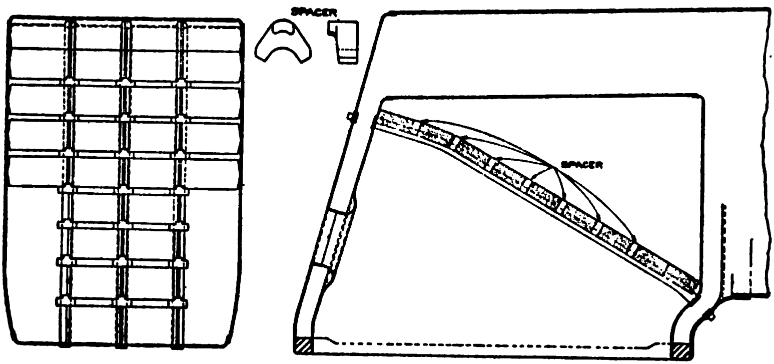


Fig. No. 16

Security Mixing Furnace of the Spacer Block Type. Here the rows of Standard Security Arch brick are separated by means of a special spacer block, and the perforated arch so formed extends the full length of the firebox on the inner rows. The side brick are left out of the rear corners, as shown in the plan view, in order to provide sufficient area through the arch for the passage of the gases.

SECURITY ARCH AND FLUE PROTECTION

The effect of the brick arch upon the reduction of fluework is shown by the Committee Report contained in the Master Boiler Makers' Proceedings of 1912. Data was presented by 50 roads, of which 35 reported an average reduction of 45 per cent. in flue work; 42 reported a reduction in flue failures; 37 reported less trouble with flues plugging; and 29 reported less trouble with honeycomb. One large eastern trunk line, which kept an accurate record of the number of times the flues were calked during a period of several months before arches were applied, and for a period of similar length after arches were applied, found that before arches were applied the flues were calked 4,000 times, and after arches were applied they were calked 1,000 times—a reduction of 75 per cent. due to the protection afforded by the arch in preventing cold blasts of air, that enter through the open fire door and through holes in the fire, from striking and chilling the flues.

Since the above report was made, the use of the arch has extended to practically all roads in the United States and Canada, and similar results are being reported from most of them.

SECURITY ARCH AND HONEYCOMB

Honeycomb on the flue sheet seems to be due primarily to the presence of sulphur and iron impurities in the coal. These impurities in combination are known as iron pyrites, with an indicated composition of FeS_2, i. e., one atom of iron combined with two atoms of sulphur to form a molecule of pyrites. This substance can be burned, forming oxides of sulphur and iron; the former passing out at the stack as a gas, and the latter being left behind as a constituent of the ash. If the oxygen supply in the firebox is insufficient, the iron pyrites decomposes at the comparatively low temperature of 800 to 900 degrees Fahrenheit, and loses one atom of sulphur; forming a sticky, molasses-like slag of iron sulphide, with an indicated composition of FeS. If the iron sulphide in this form is thrown against the flue sheet or crown stay heads, it adheres firmly to them, and builds up the substance familiarly known as honeycomb. This iron sulphide, however, can also be burned, and if it is thrown against the arch by action of the draft, it adheres firmly to it and the remaining sulphur atom is driven off by the heat at a temperature of 1,650 degrees Fahrenheit, or, if oxygen comes in contact with it, it is decomposed and burned, forming oxides of sulphur and iron as before stated.

ARCH TUBES

The Committee Report on Brick Arches read before the Traveling Engineers Association in 1911 contained data relative to tests made to determine the efficiency of the Security Arch and Arch Tubes. One paragraph of this report reads as follows:

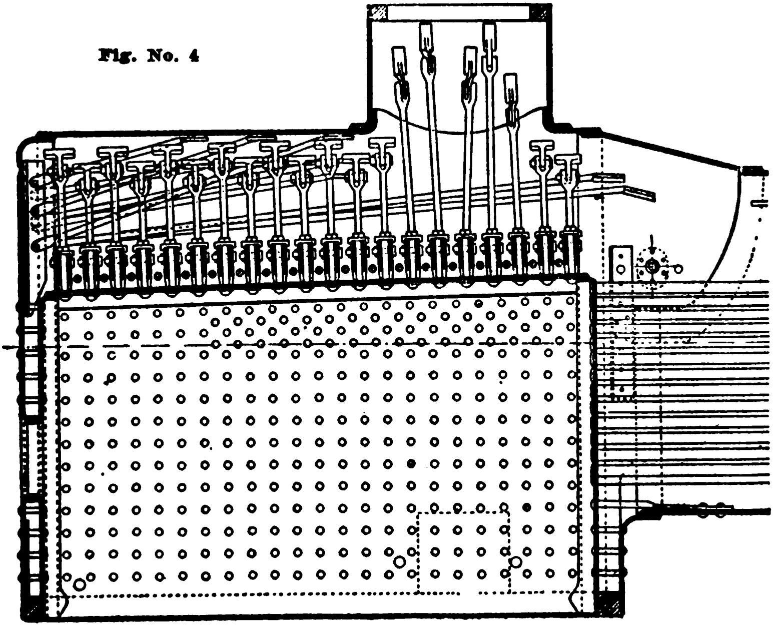
"With the brick arch and arch tubes, the equivalent evaporation per pound of dry coal shows an increase of 14.9 per cent. over the arrangement without the brick arch or arch tubes, and a gain of 9.3 per cent. over the arrangement without the brick arch but with arch tubes. Therefore, the increased circulation and heating surface due to the arch tubes caused a gain of one-third of the 14.9 per cent. increase, while the brick arch must be accredited with the remaining two-thirds of that increase."

LOCOMOTIVE BOILERS

Fig. No. 4 shows the construction of the old style crown bar boiler.

The mud ring at the bottom of the water legs will be seen and rigid staybolts fastening the sheets together. Crown bars will be seen extending crosswise of the crown sheet and the sling stays attached to the crown bar at the bottom end having the top riveted to the roof or wrapper sheet and some extending up into the dome.

Fig. No. 4



Head braces will be seen attached to the back head and points along the inside of the shell.

The crown bar is bolted to the crown sheet by means of crown bolts.

This type of locomotive boiler has a conical sheet attached to roof sheet and to the cylindrical portion of the boiler. The dome is located directly over the firebox B, necessitating the use of crown bar and sling staying as shown in Fig. 4. The sling stay is attached to the crown bar by a pin or bolt. The crown bar boiler provides for expansion of the crown sheet, but its chief disadvantage is that it prevents the proper cleaning of the crown sheet. The crown bars retard circulation over the crown sheet and allow mud to become lodged between them.

The crown bar boiler can always be distinguished from the radial stay by the location of the dome, i. e., crown bar boiler, the dome is over the firebox, whereas the radial stay boiler it is ahead of the firebox.

Fig. No. 5 shows the construction of the radial stay boiler.

It will be noticed the radial stay is similar to a staybolt but having a greater length. The forward end of the crown sheet has two rows of sling stays for the purpose of allowing expansion to take place.

Throat stays will be seen in the lower belly of the boiler attached to the tube sheet and riveted to the boiler shell.

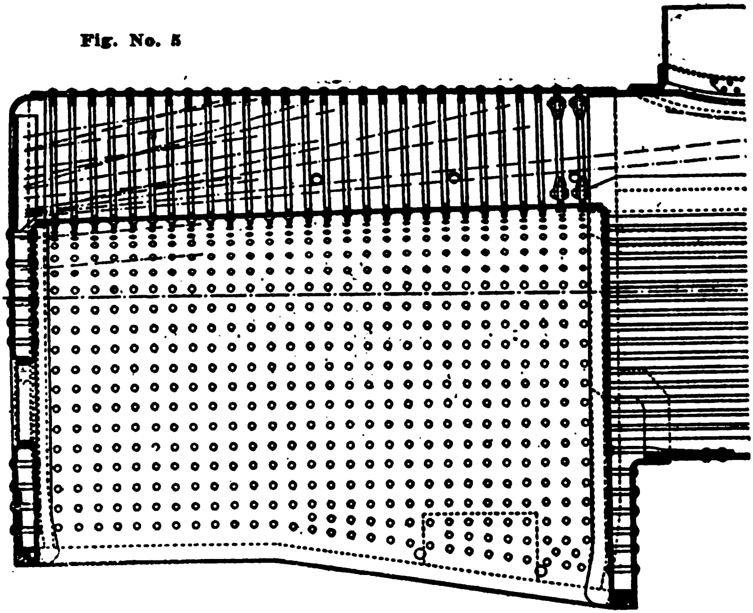
The broken lines over the crown sheet show the position of the back head braces.

The dotted section near the mud ring of both Figs. 4 and 5 show the location of the expansion plates or pads.

The dome is located ahead of the firebox; it must be located here with this type of staying.

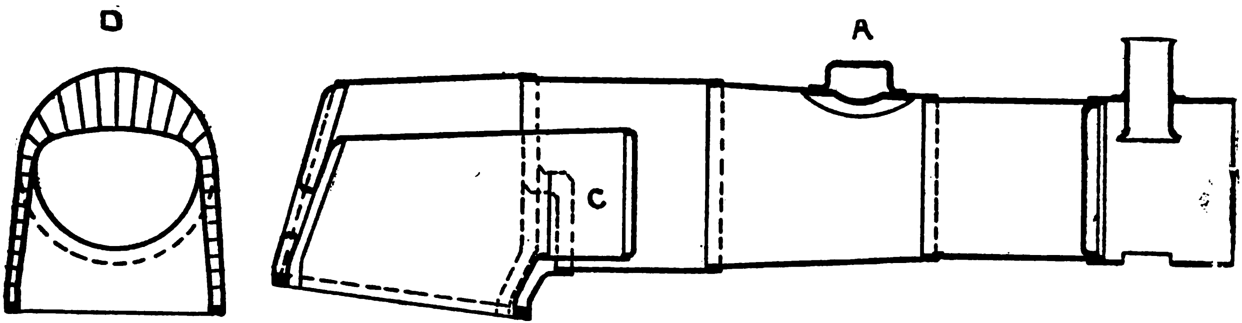
Both these types shown in Figs. 4-5 are stayed by rigid staybolts.

Fig. No. 5

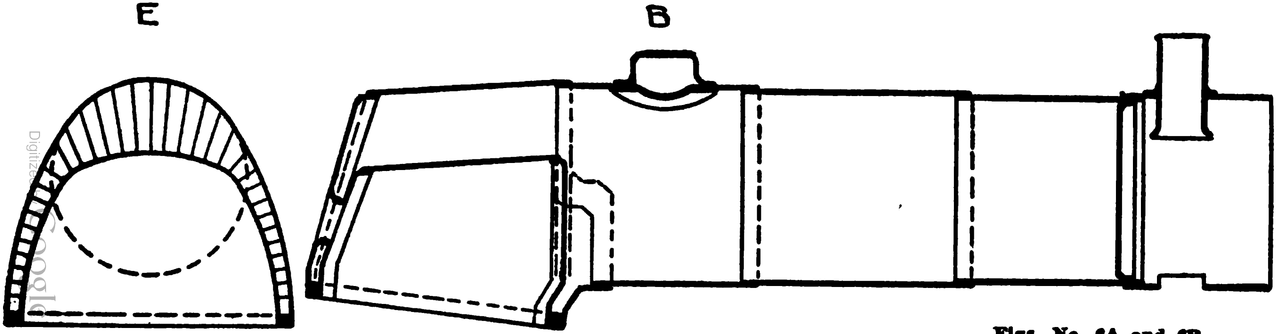


THE EXTENDED WAGONTOP BOILER

Fig No. 6A shows the extended wagontop boiler having the same general outline of the crown bar boiler, except that the conical sheet is two courses ahead of its location in the older types. By placing



RADIAL STAY TYPE BOILER



Figs. No. 6A and 6B

WOOTEN TYPE BOILER

the dome ahead, radial stays may be used, thus doing away with the crown bar and its disadvantages. The crown and roof sheets are nearly similar arcs, giving the radial stays a straight line pull when under tension of steam pressure. D shows an end view of the firebox. C shows the combustion chamber.

The radial stay used in this type of boiler is simply a long staybolt which is screwed through both the crown and roof sheets, although radial stays of the flexible type are largely used now.

The barrel construction is generally in three courses with the usual course for the smoke box.

Staybolts are provided to hold the firebox sheets together and to resist the pressure acting on them.

The extended wagontop boiler is generally of the larger types and is constructed to be mounted on top of the main locomotive frame. This gives a better opportunity for increasing the size of the firebox and enlarging the grate area.

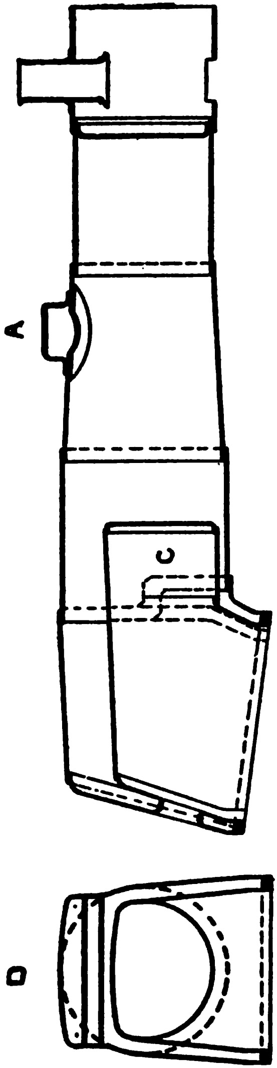
Fig. No. 6B shows the construction of the Wooten type boiler.

This type of boiler has a large grate area and is used to burn hard coal. The crown sheet is not so high as found in the radial stay boiler. The barrel construction is known as the straight top type.

E shows an end view of the firebox.

THE BELPAIRE BOILER.

Fig. No. 7 shows the Belpaire boiler having a flat roof and crown sheets the purpose of which is to give a straight pull on staybolts and to increase the steam



BELPAIRE BOILER
Fig. No. 7

space. Referring to Fig. 7, inside and outside sheets are stayed by staybolts; stay rods pass from one side to the other over the crown sheet, thus increasing the stiffness of both sheets; crown stays pass from the crown sheet to the roof sheet and pull in a straight line.

Gusset or crowfoot stays are used on the heads. Flues pass through the cylindrical part of the boiler and are expanded into the flue sheets.

The dome is located ahead of the firebox and performs the usual duty of providing a place to locate the throttle valve and turret pipe, thus insuring so far as possible dry steam to the cylinders, injectors, lubricators, etc.

Throat stays are attached to the flue sheet and barrel and so constructed to provide for expansion and contraction. The barrel of the boiler is constructed, three or more courses of separate sheets telescoping each other, thus adding greatly to the stiffness of the barrel. The front flue sheet is flanged outward to provide caulking edges; a separate sheet forms the smoke box for the draught appliances. The above is true of the foregoing types.

Some railroads use Belpaire boilers entirely. They have the advantage of greater steam space and the crown sheet construction provides a means for placing the radial or crown braces in a direct lines, i. e., the crown sheet and roof sheet are so lined that there will be a direct tension on the bolt when under pressure.

Fig. 8 shows the construction of a modern extended wagontop boiler having radial stay construction and the combustion chamber; water bars or circulating pipes extend from the lower front water leg to the back sheet as shown. The circulating pipes assist in circulating water in the lower portion of the boiler, add to the heating surface and support the brick arch.

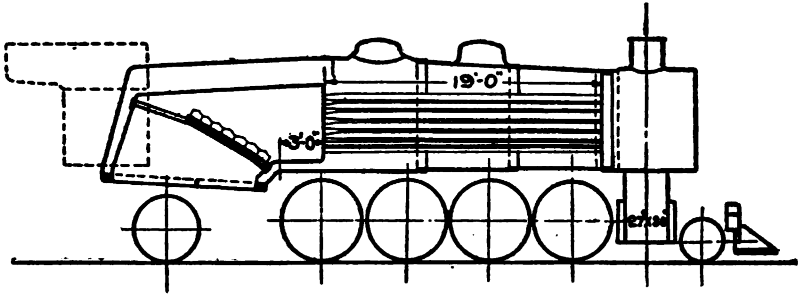


Fig. No. 8B

The firebox sheets should be made thin to assist in conduction of heat to the water. Side sheets on engines carrying 180 to 200 pounds of steam would have ⅜ sheets on the side and ½ to ⅝ tube sheets. The latter being made thicker for the purpose of holding tubes. Crown sheets should be given the same thickness as side, which should be supported by ⅞ to 1⅛ radial stays, which should be spaced to allow not over 5,500 pounds per square inch of cross sectional area.

The large firebox has the advantage of direct heating surface, and in addition the large firebox provides for a slower rate of combustion resulting in economy in fuel consumption, up to a certain limit.

Grates are set in the firebox and are supported by a trunnion, providing a method for shaking by use of the shaker lever and its connections.

Many boilers today have a combustion chamber having the advantage of increased direct heating surface and makes it unnecessary to use a long tube.

Expansion of the boiler is provided for by expansion plates attached to the engine frame, having pads attached to the boiler, surfaces of each made so that the boiler may move backward and forward with minimum friction. This allows the boiler to move as its temperature changes. See Figs. 4 and 5.

The expansion plate should be kept well lubricated.

The fountain or turret is attached to the roof sheet inside of the cab. Its purpose is to supply dry steam to the injectors' lubricators, steam heat regulator, blower valve and other connections in the cab.

The turret provides for all these connections and makes it unnecessary to cut into the boiler shell at more than one place. A steam pipe leads from the dome to the turret, the upper end located near the seat of the throttle valve.

The dome is provided with a cap to which it is securely bolted and made tight by the use of a copper gasket. The dome cap provides a method for internal inspection of the boiler.

THE BLOWER

The blower is a pipe connected to the turret in the cab passing down in front of the fireman's seat, with a suitable valve, extending into the smokebox where it is bent up so to convey steam to the center of the stack.

The blower operation is very simple. When steam is admitted to the stack, it entrains or pulls the air out of the smokebox, thereby reducing the atmospheric pressure; the air on the outside rushes through the grates and fuel-bed, increasing the rate of combustion.

STAYING FIREBOXES AND ITS REASONS.

Locomotive type fireboxes are stayed by staybolts for the purpose of adding stiffness. For example, all pressure acting on a flat surface tends to round it out, while the pressure acting on a round surface like that of the boiler shell exerts a tensile strain, or in other words, a strain along its fibers. This can be more plainly seen by taking a piece of paper, holding it on four corners and pressing it lightly at the middle. You will find it quite easy to move it out of its shape or distort it, but take the same piece of paper and try to pull it straight along its fibers. For example, take it in both hands and pull it apart without crumbling it up, you will find great effort is necessary to pull or break apart. This shows the reason for the use of staybolts on flat surfaces or fireboxes and not on the cylindrical portion of the boiler.

RIGID STAYBOLTS

Rigid staybolts are provided with a small hole drilled in the center, known as telltale holes. They provide a means of ascertaining whether the staybolt is broken. The reason for drilling the outer end of the staybolt is: the inner sheet expands and contracts more under the varying temperatures than the outer and it gives the inner firebox sheet a leverage; on the bolt since the outer sheet is relatively at a standstill, this constant moving of the inner sheets causes crystallization of the staybolt near the outside sheet and after the bolt becomes broken the water or steam will issue from the small hole, indicating its defective condition.

There is a further reason for breakage near the outside sheet and this is its thickness. The outside firebox sheet is much thicker than the inside, therefore, offers a greater resistance. Experience tells us that the forces of expansion and contraction tell on the inside firebox sheets, as it is not uncommon to find them cracked or highly crystallized after a few months of service. The introduction of the flexible staybolt has helped these conditions greatly.

The hammer test is made to determine broken stays and the condition of the plates. The test for locating broken stays is as follows: A man holds a sledge hammer against one end of the stay while the inspector taps the other end with a small hammer. If the stay is solid, the blow given by the hammer reacts quickly; but if the stay is broken there is a dull sound and very little reaction from the blow. In some cases it is difficult to determine a solid stay from one that is partially cracked, especially when the broken ends are in close contact. A good plan in such tests is to subject the boiler to an air pressure of from 40 to 60 pounds per square inch; this pressure is sufficient to keep the broken or cracked stays apart.

FLEXIBLE STAYBOLTS

The ordinary or rigid staybolt depends largely on the quality of material used to obtain the best results in firebox service. As a connecting member to hold the firebox and outer shell of boiler together under stress of boiler pressure, it is simple and strong, but so rigid that firebox sheets under expansion are greatly restricted, and bend and buckle under the resisting influence of the rigid stay, thus exerting stresses on both sheet and staybolt, causing crystallization that affects and shortens the service life of both staybolt and firebox sheets.

The bending of a solid staybolt is but slight, but when frequently repeated under the stress of sheet expansion, a fiber stress is imposed, sufficient to fatigue the strength of the staybolt structure, and operates with like effect in breaking down the strength of the

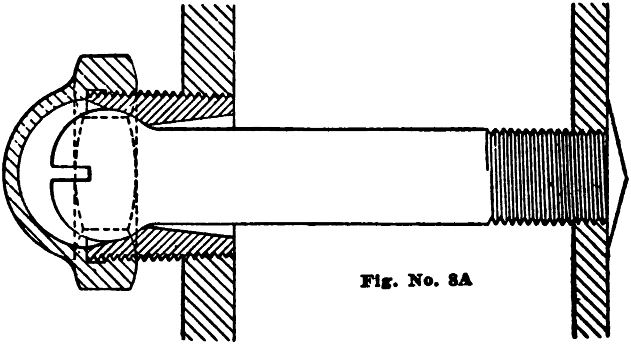


Fig. No. 8A

sheet structure, producing as it does a condition of sheet distortion, bending, and buckling, by being too rigidly connected.

Fig. 8A shows the flexible staybolt used extensively today on locomotives. The bushing or seat is screwed into the outside sheet and the inner end of the staybolt is screwed into the inner firebox sheet.

The expansion of the inside sheets causes the staybolt to move on the ball joint, whereas with the rigid type the bolt has to bend; this causes it to become crystallized.

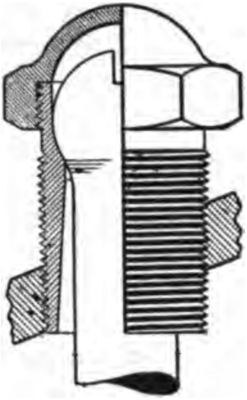


Fig. No. 8

Fig. 8B shows the construction of a flexible radial stay. There are several types used but the principle is about the same.

BOILER TUBES

In firetube boilers, of the locomotive type, the tube hole is larger than the tube, and a copper ferrule is used to fill the space. This is first rolled in lightly, then the tube is rolled in tight. It is necessary to fill up this space to prevent cracking the tube in expanding, which is done by using thin strips of copper about 1 inch wide to fill up the space. Whatever material is used for this purpose should be soft, to prevent stretching the tube sheet, and copper seems to give the best results.

After the tube has been expanded, the ends should be beaded over tight against the sheet, which can best be done with beading tools. The bit of these tools should be about 3/8 in. wide. It is used to draw the edges over, striking it lightly to prevent splitting, and working all around the end, and to draw it down flat against the sheet.

The tube is beaded over to prevent burning it off. The heat absorbed by the tube end will be conducted to the water, keeping the same greatly below its melting temperature.

Generally the tubes in the firebox are beaded while those in the front end are not.

Welding flues in the back flue sheets of locomotive boilers have generally proved successful in good water districts, but in bad water districts trouble is experienced and a good many failures are reported. The possibility of eliminating troubles from leaky flues by welding the ends of the flues to the tube sheet was at first hailed with enthusiasm, and today thousands of locomotives are giving successful service with flues applied in this manner. In bad water districts, however, something beyond the ordinary method of welding is apparently necessary. On the Chicago and Northwestern, as explained by Mr. Pratt at a recent Master Boiler Makers' convention, the welding of small flues to the back flue sheet in bad water districts was not a success, and so a new method had to be devised. A recess was cut in the back flue sheet, into which the beads of the flues were turned and then welded over so as to form a thorough soldering of the joint between the flue and the sheet. This, it was expected, would permit the expanding of the flue without breaking the weld loose between the flue sheet and the flue. Another method of overcoming this trouble, adopted by a Southern road, consists in applying the flues in the usual manner without welding and then whenever the flues start to leak they are welded up, thus prolonging their length of service.—The Boilermaker.

LOCOMOTIVE BOILERS IN GENERAL.

Summing up the construction of a locomotive boiler a few general points will be dwelt upon.

Material should be the best and conform to the physical and chemical recommendations or standards of the American Railway Master Mechanics' Association.

Firebox material should be elastic to resist corrosion and crystallization—tensile strength running as low as 45,000 pounds per square inch. It should be highly homogeneous or dense. It is desirable to have the firebox plates of a uniform density or grain (sometimes called), because if two plates of different density are placed together, one will corrode faster than the other. The density of boiler plate is determined by weighing. This will also show up any fissures or places in the metal where gas lodged when the metal was poured from the ladle. An example of this would be, for instance, the weight of one cubic foot of soft steel is 490 pounds—if a cubic foot of boiler plate accurately measured weighs less than this it is evident that there is some metal missing.

Boiler plate should have elasticity to prevent defects creeping in which are due to the manufacture, i. e., rolling, punching and makeup.

Tensile strength to insure a strength that will overcome the strain the boiler will be subject to and still have the plate as thin as consistent with the pressure to be carried.

Ductility—The ability of the material to be drawn into wire without rupturing. This characteristic has the ability to resist the buckling action of the seams preventing crystallization of the material.

Steam domes should be made of the same quality of material as the boiler shell; points which extend longitudinally should be double butt and strap construction. The opening into the shell should be double riveted with a reinforcing collar attached thereto.

THE SIZE OF A BOILER

Size is only one part of the problem, instead of being the chief feature as it has been considered in the past. It is now a question of balancing all factors of the locomotive to make and to absorb the maximum amount of heat per unit of weight. The day of ratios between grate area, heating surface and cylinder volumes has given place to a day of providing steam to produce definite amounts of cylinder horsepower within defined limits of weight.

That is, in the past the heating surface was determined by the volume of the cylinders using a factor to multiply by and reading off the result as so many square feet of heating surface for a given size of cylinder, but the modern method is to take the cylinder horsepower, which simply means what horsepower is the engine to develop at its maximum effort. When the cylinder horsepower is determined the problem resolves itself into how much fuel must be burned to convert the water into steam necessary to supply the engine.

From 25 to 29 pounds of water per horsepower per hour is required for modern locomotives.

FIREBOX WATER LEGS

The firebox design. Late years there has been a general trend toward wider water spaces, about 4½ to 5 in. for the sides and 5½ to 6 in. at the front being general practice.

STEAM SPACE

Steam space in a locomotive boiler should be about 1/6 the volume of the boiler.

VALUE OF DIRECT HEATING SURFACE

Direct heating surface is that indirect contact with the fire, the firebox sheets and combustion chamber.

The accepted value assigned to firebox and tubes Steam space in a locomotive boiler should be 6 1-6 the volume of the boiler.

respectively averages about 6 to 1 (1 square foot of direct heating surface is equal to six square feet of tube heating surface), with special designs of firebox claiming a ratio as high as 12 to 1. The most effective ratio of firebox volume to grate area is approximately from 5.5 or 6 to 1 for bituminous coal, and 4.5 or 4.85 to 1 for anthracite coal.

TUBE LENGTH

The proportion of tube length to diameter is 100 times the inside diameter in general practice. Longer tubes do not require any greater spacing than reasonably short tubes.

The use of long tubes is not favored, for, while the total evaporative capacity of the boiler may be increased by their use, the rate of evaporation per unit area of heating surface is lower, and discounts the theoretical increase in capacity in this connection, tests show that there is a great variation in the evaporation value of the boiler tube, about one-half of the heat being transmitted in the first quarter of the tube.

SUPERHEATING SURFACE

The ratio of superheating surface to total saturated heating surface is from .198 to .29, the average for modern locomotive being about .27 to .29 for boilers with combustion chambers, and .20 to .22 for boilers without combustion chambers.

GRATE AREA

Grate area required for bituminous coal is based on the assumption that 120 lbs. of coal per square foot of grate per hour is a maximum figure for economical evaporation. While 200 and 225 pounds have at times been burned in small, deep fireboxes and the engines made to produce sufficient steam, it is wasteful of fuel and it has been found, after numerous and careful tests, that the evaporation per pound of coal under these conditions is very low. If, on the other hand, the rate of combustion is too slow, economical results will not be produced, owing to the fact that at least 20 per cent. of the coal burned produces no useful work in hauling trains, but is consumed in firing up, waiting at round houses or terminals, on side tracks, or to the fact that the greater portion of the time locomotives are used at considerably less than their maximum power.

An evaporation per hour of 6¾ lbs. of actual water per pound of bituminous coal has been assumed as a fair average value. It has been shown that a horsepower can be obtained from 27 lbs. of saturated steam. Therefore, 27 divided by 6¾ equals 4 lbs. of coal per horsepower hour for saturated steam locomotives.

Maximum rate of combustion is taken at 120 lbs. per square foot of grate per hour with coal of good quality, containing say 14,000 B. T. U. The grate surface required will equal H. P. times 4 divided by 120, dividing the H. P. directly by 30.00 for saturated steam.

For hard coal, the grates should be proportioned for a range of from 55 to 70 lbs. of coal per square foot per hour according to the grade of the fuel.

THE ASHPAN

The ashpan is a vital factor in the production of heat. To provide air enough for a big firebox and put the air where it is wanted is a very important matter. The speed of gases at a certain point in a big firebox, working hard, is 180 miles per hour. To supply air enough and how to provide in the ashpan sufficient to maintain atmospheric pressure in the ashpan at maximum rate of power development is sought.

The minimum ashpan opening desired to give sufficient air to the fire is 14 per cent. of the grate area.

Grates should be constructed to give the maximum air space or use up as little of the firebox area as possible consistent with the strength required.

Some roads use grates having 30 to 45 per cent. air openings, as compared with the total area of the inside dimensions of the firebox at the base.

WATER

Nearly all water contains in solution the salt of some metal, dissolved in passing over the mineral beds of the earth. One of the most common of these salts is calcium carbonate, which is a compound made up of one part calcium and one of carbon and three of oxygen.

Calcium is an element; it is a silver white metal; it is never found in an uncombined state. When exposed to the air, it soon becomes coated with a white substance, calcium oxide or lime.

CALCIUM CARBONATE is only slightly dissolvable and is less dissolvable in warm than in cold water. Its presence alone in feed water would cause little harm because of the very small quantity which the water could hold in solution.

In general, feed water containing magnesia, lime and mud will cause scale to adhere to the heating surfaces, while animal fats, oils, and soapy substances will cause foaming.

BOILER SCALE AND PITTING

Pitting

Pitting is generally found on the water line. It is due to the chemical action of water.

Forge scale or iron scale, which is sometimes contained on safe-ended flues, small particles of coke fed through injectors on coke burning engines. Small pieces of copper ferrules left in the boiler or brass chips, any of these may cause a galvanic action and a subsequent dissolving of the tubes and boiler shell called pitting.

GROOVING

Grooving in a boiler is due to the bending action of the seam, but primarily to oxide of iron rust having formed as a thin scale. These scales keep breaking off as the grooving deepens. This condition is commonly found on lap seam boilers because of their construction, invite crystallization and adding to this impure water, we have a dangerous condition.

BOILER SCALE is caused by the adhesion on the boiler plates and flues of impurities from the boiler feed water which, aside from sediment, consist principally of carbonate, magnesium carbonate, magnesium sulphate and calcium sulphate.

Scale should not be allowed to accumulate. Not only is it detrimental to good economy, but it is a source of danger to the boiler. When a hard thick scale forms, the plates and tubes become overheated and the strain resulting greatly shortens the life of the boiler.

Disastrous explosions and burst tubes causing loss of life are often traced to scale. It is very seldom that one hears of a serious accident from a clean boiler.

It has been proven that a coating of hard scale 1/15 inch thick on the inside of a boiler shell will cause a loss in fuel of over ten per cent.

DISTINCTION BETWEEN FOAMING AND PRIMING.

When the steam space contains unbroken bubbles of steam caused by use of dirty water, the boiler is said to foam; and to prime if water is carried by the steam from the boiler, from overloading or carrying the water level too high.

Water in the boiler foams because it contains matter in suspension making it lighter. For example—place a coffee pot on a hot stove with ordinary water in it, then bring the water to the boiling point, the water will simply boil, but not run over the top.

Then next apply coffee, bring it to the boiling point, what happens? It will boil over. Why? Because the coffee makes the water lighter, that is, the coffee is lighter than the same volume of water and hence causes the pot to boil over. This is the reason for the priming of a dirty boiler or water having much matter in suspension.

SUPERHEAT LOCOMOTIVES

The principle of a superheater, referring to Fig. 17.

Assume the Boiler "A," having a steam pressure of 200 pounds supplying the engine "C" through the steam pipe "B," and passing through the coil "C" having a fire directly under it. The fire "D" raises the temperature of the steam in the coil "C" from 387 to 600, but the pressure, of course, is the same, simply made it 213 degrees hotter. The steam passing into the engine "E" does not condense because it is too hot.

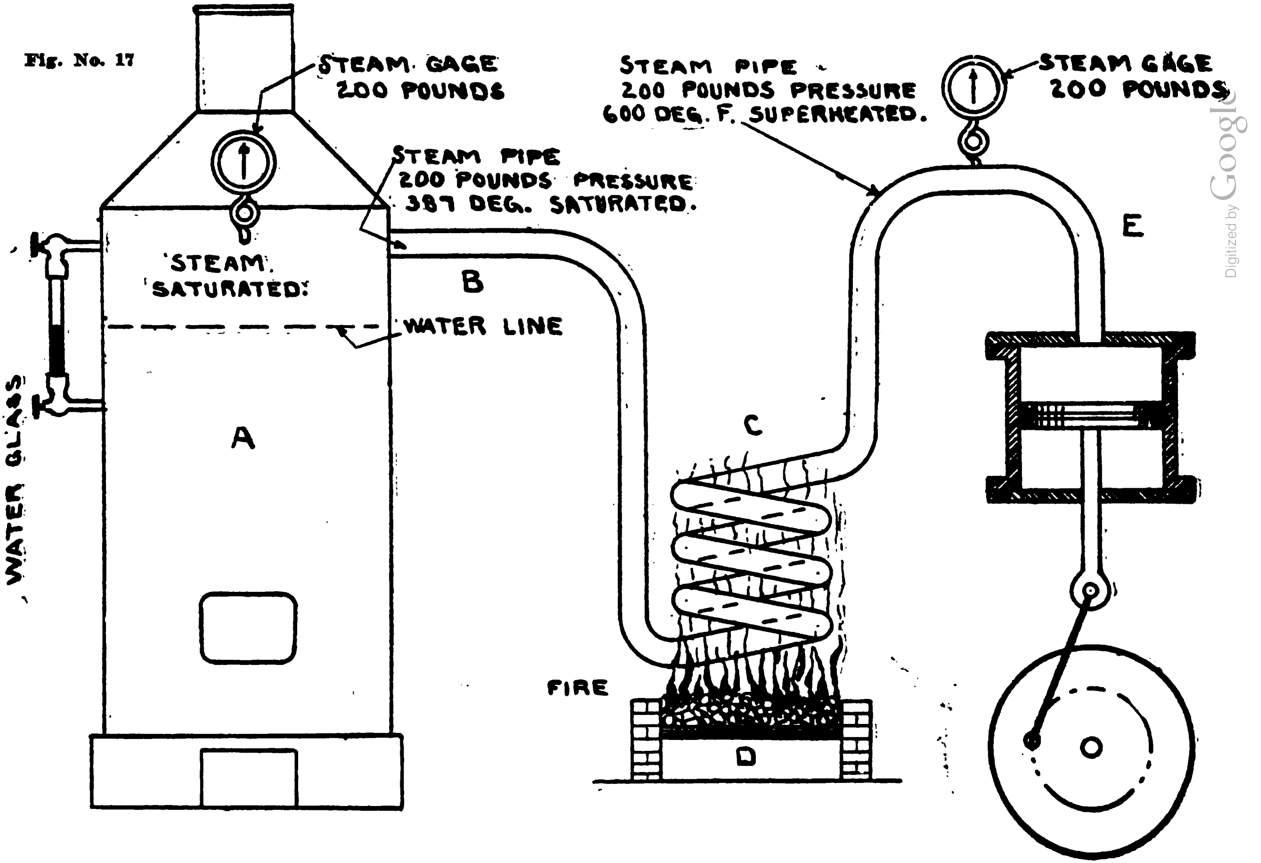
Some men are under the belief that the superheater increases the pressure in the cylinders or as it passes through the superheater. This is not true; by referring to the cut it will be seen that any increase in pressure at the coil "C" would go back into the boiler "A," and could not increase the pressure above that carried.

Referring to Figs. 18 and 19, it will be seen that 25% of the steam entering the cylinders condensed, while that entering the cylinder in a superheated state did not condense at all. This is the all-important reason for use of the superheater.

It will be seen, therefore, that the primary purposes of a locomotive superheater are, first, to eliminate cylinder condensation which runs as high as 25% of the steam used in the cylinders of a locomotive. Second, to increase the expansive force of the steam. Third, to economize in fuel and water.

It is well to remember that there is a difference in

Fig. No. 17


STEAM GAGE 200 POUNDS
STEAM PIPE 200 POUNDS PRESSURE 600 DEG. F. SUPERHEATED.
STEAM GAGE 200 POUNDS
STEAM PIPE 200 POUNDS PRESSURE 387 DEG. SATURATED.
STEAM SATURATED.
B
E
WATER LINE
WATER GLASS
A
C
FIRE
D

temperature of over 340 degrees between the steam in a locomotive boiler at 200 pounds gauge pressure and the atmosphere at the average temperature. The material used in locomotive construction radiates heat very fast and therefore causes a large difference in the temperature of the cylinders as compared with that of the steam in the boiler. By the use of a superheater the temperature of the steam is so increased that condensation cannot take place while it is working through the cylinders. This, of course, is due to the fact that the steam temperature does not get low enough to condense. If we can stop the condensation of steam in the cylinders while doing its work it simply means in a sense that we have added 25% to the capacity of the boiler, i. e., the boiler will have 25% less steam to supply and the same proportion less water to evaporate, and, of course, the engine will steam better. This is clearly shown in practice. The increase in steaming quality of the engine is due to eliminating the moisture in the saturated steam and cylinder condensation. The moisture of water in a suspended state often reaches as high as 8 per cent. in a locomotive boiler.

Some of the first comparative tests made during the development of the superheater showed a difference of about 16% in steam consumption in the saturated over the superheater locomotive. This has been increased by later improvements in design until we now have 25% saving in steam consumption in favor of the superheat locomotives.

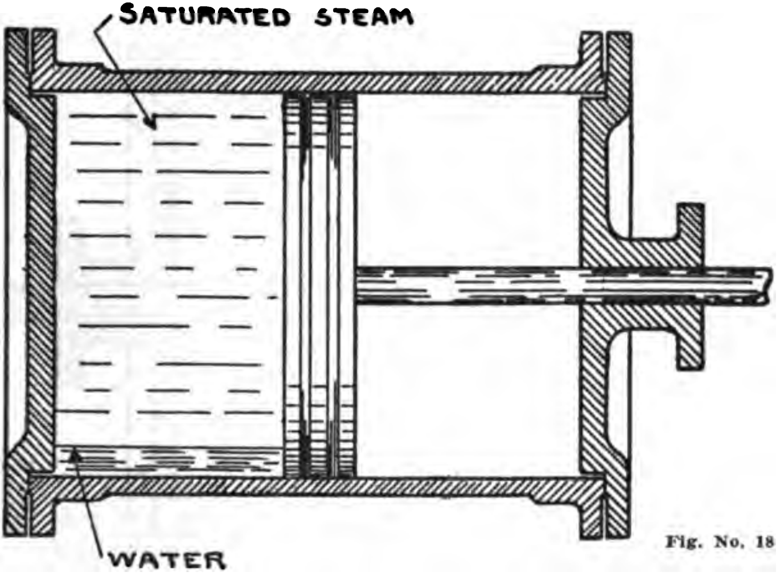


Fig. No. 18

25% OF STEAM ENTERING CYLINDER CONDENSED.

To explain the second purpose it is well to bear in mind that the expansive force of a volume of steam is increased 12½% for each 100 degrees of heat imparted to it above its ordinary temperature (Fahr.). That is, the more we heat the steam after it leaves the boiler the more it will expand, that is, for all practical purposes.

With a reduction of 25% of the steam required for the cylinders then it naturally follows we decrease the demand on our boiler for steam to the extent of 25%, the result is a saving of 25% of the fuel burned.

Large savings in water are obtained by the use of the superheater for the following reasons: The super-

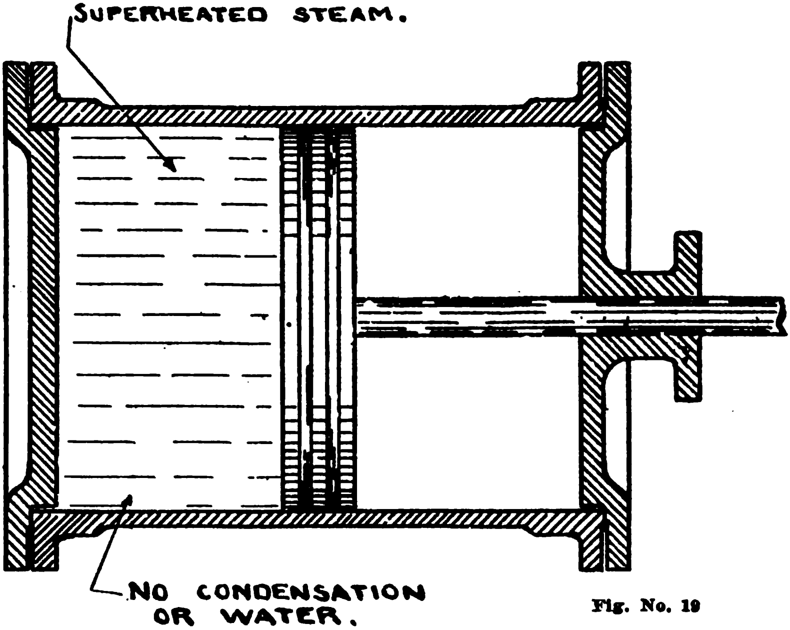


Fig. No. 19

heater engine when correctly operated will show a decrease in the steam condensed in the cylinders to the extent of 25% as previously stated, and in addition to this the superheater will dry the existing moisture from the steam which roughly is 3% to 10% of the steam entering the dry pipe. It is conservative to estimate the average saving in water at 25%—tests have shown even better than this.

Many railroads have increased the diameter of cylinders and lowered the steam pressure to give the same tractive power. It is well to remember that in order to have the engine deliver its effective rating, superheated steam must be used and water kept down ¼ to ½ glass and the firing done properly. See that the steam is being superheated, otherwise, if you get saturated steam in the cylinders, an engine failure will probably result, since saturated steam will condense 25% of its volume entering the cylinders, and since the cylinders are much larger in proportion to the heating surface, of course they will increase to amount of steam required and overtax the boiler.

The following pages will give a general description of the superheater as applied to a locomotive:

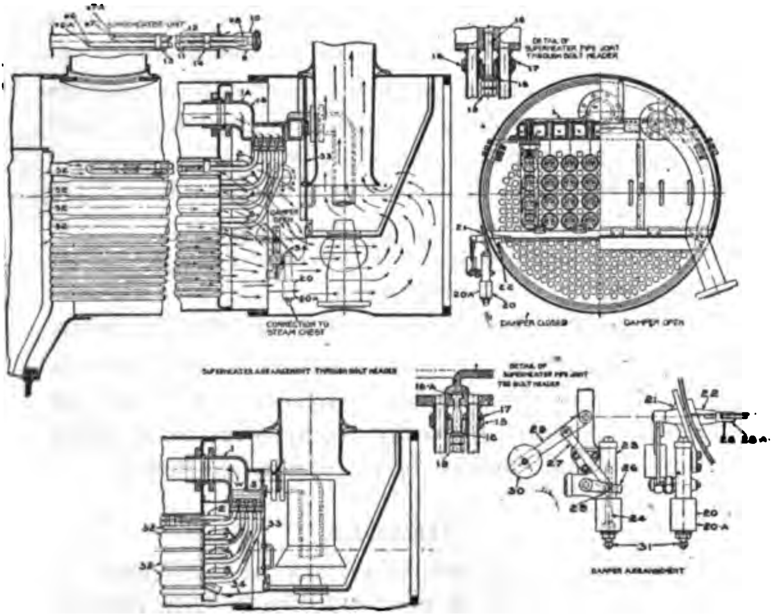
The superheater as applied to locomotives consists of three or more horizontal rows of large boiler flues across the upper part of the boiler, each containing a superheater unit. The usual size of these flues is 5⅜ inches, or 5½ inches outside diameter, except at firebox end, where the diameter is reduced to 4½ inches by swaging. The superheater unit is a continuous tube formed of four seamless steel superheater tubes.

The superheater as applied to locomotives consists essentially of the superheater header and a series of superheater units, generally arranged in two or more horizontal rows across the top of the flue sheets.

HEADER

The superheated header replaces the ordinary tee or nigger head. It is provided, like it, with connections for the dry pipe and steam pipes, but has, in addition, internal walls, which prevent the direct flow of steam from the dry pipe to the steam pipes. The connecting passage between the dry pipe and the steam pipes is provided by the superheater units. This insures all steam passing through the superheater units on its way to the cylinders.

The units (see Fig. 20) consist of a continuous pipe, formed of four seamless steel superheater pipes. The front ends of these units are bent and clamped to the conical seats in the face of the superheater header in the smoke-box, as shown.


SUPERHEATER UNIT
DETAIL OF SUPERHEATER PIPE JOINT THROUGH BOLT HEADER
CONNECTION TO STEAM CHEST
DAMPER CLOSED
DAMPER OPEN
SUPERHEATER ARRANGEMENT THROUGH BOLT HEADER
DETAIL OF SUPERHEATER PIPE JOINT TEE BOLT HEADER
DAMPER ARRANGEMENT
16-A
17
15
16
21
22
23
24
25
26
27
28
29
30
31
20
20-A
32
33
34

SUPERHEATER ARRANGEMENT TEE BOLT HEADER

Fig. No. 20

The connection is made steam-tight by ball joints, the balls being formed on the ends of the pipe. These units are placed in the superheater flues, which are 5⅜ inches or 5½ inches outside diameter, depending upon whether used with the 2 inch or 2¼ inch boiler tubes. They extend full size from the front flue sheet to within 8 inches of the firebox, where the flue is reduced to 4½ inches outside diameter by swaging.

In operation, part of the hot firebox gases flow through the large flues. A portion of their heat is absorbed by the pipes of the superheater units and transferred to the steam passing through them on its way from the dry pipe to the cylinder. As a result the steam has a higher temperature on reaching the cylinders than when it left the boiler; briefly stated, it is superheated steam.

The superheated units, which extend nearly through the tubes, are exposed to the combustion gases, whose temperature ranges from 1,600 to 600 degrees Fahrenheit, within the tubes. The saturated steam passing through the enclosed pipes and exposed to the temperature above quoted is raised from 200 to 220 degrees Fahrenheit above that of the steam in contact with the water. While there is a loss in the temperature of the superheat in passing through the pipes to the cylinders, yet there is sufficient increase over the temperature of saturated steam in the cylinders to provide against cylinder condensation. By this increased temperature in the steam, a saving in steam consumption of 30 per cent. and a corresponding saving of 25 per cent. in fuel (may be realized) by the use of a superheater in a locomotive boiler, as compared with a similar boiler operating under the same conditions with saturated steam.

To prevent the fire damaging the ends of the superheater units, where they come close to the firebox, a portion of the firebox, including the superheater flues, is boxed off. One side of this box is formed by the superheater damper, which is automatically operated, except under special conditions, by the admission of steam to the cylinders. It is so arranged that on supplying steam to the cylinders the damper will open and permit the free flow of gases from the firebox through the superheater flues to the smokebox. When the supply of steam is stopped the damper is automatically closed, by the weight of the damper shaft arm, thereby shutting off the flow of gases and preventing overheating of the unit pipes.

Some special conditions of service make it advisable to have the damper open except when the blower is in use. When this occurs the damper cylinder is connected with the blower pipe and the damper remains open except when the blower is on. The steam from the blower pipe in this case closes the damper while the weight automatically opens it when the blower is shut off.

The deflector plates should be made to fit tightly and the manhole in the netting should be large enough so that the deflector plates can be removed without removing the netting.

OPERATION

The general operation of the superheated locomotive is the same as that of the saturated steam locomotive.

The watchman should never fill the boiler so full that the height of water cannot be located by the glass and gauge cocks.

Cylinder cocks should be left open to drain the cylinders, etc., while standing.

In starting, the cylinder cocks should remain open until dry steam appears and the reverse lever should be placed in full gear to insure oil lubrication the full length of the valve bushings.

Care should be taken to prevent slipping.

The hostler should always open cylinder cocks before releasing brakes.

Where water is carried over to the superheater, closing the throttle does not stop the supply of steam until after the water in the superheater has all been evaporated and used.

This condition of water in the superheater means trouble in "spotting" engines, in "switching" service and is especially bad in "hump yard" service on account of the lost time in "cuts." It is ordinarily a sure sign of careless operation.

In the same service, water should be carried at the same level on a superheater locomotive as in a saturated locomotive, so that the superheater will receive fairly dry steam.

Under normal conditions steam should come from the third gauge cock with steam and water in the second, i. e., the same as in the operation of saturated locomotives.

High water will cause lubrication and packing troubles, and slow running, and reduce the coal and water economies that are available by the use of superheated steam.

Engines which do not steam freely and do not show the normal saving of 25 to 35 per cent. in water over saturated engines in the same service and with the same tonnage should have dampers and flues examined to see that the damper operates correctly and that the flues are open and clean.

If the flues are open and clean and the damper operating correctly, test the superheater, exhaust and steam pipes for leaks, the engine for blows, and see that the draft apparatus is O.K.

Leaks of the superheater, steam and exhaust pipes, flues stopped up or leaking, and the disarrangement of the draft apparatus, all interfere with the steaming of the engine and reduce the superheat by interfering with the flow of gases in the large flues. Blows in the cylinder and valve packing remove the oil from the wearing surface and cause excessive wear of parts, waste of steam and loss of power.

All these conditions should be reported and corrected at once.

If abnormal consumption of coal and water still continues, and the above conditions do not obtain, go after the "operation" and see that the superheater is used to superheat the steam and not as an auxiliary to the boiler for evaporating the water.

Where working conditions will permit, the engine should be worked with full throttle and short cutoff.

Where less than 30 per cent. cutoff is needed, further adjustments should generally be made by reducing the throttle opening rather than decreasing the cutoff.

DRIFTING

In drifting, sufficient steam should be used to prevent the suction of dirt and gases from the smokebox into the cylinders and steam chests, and insure the satisfactory distribution of the oil.

The lubrication of the cylinders and the steam chests should be constant and regular, while the engine is running. The lubricator should be started at least ten minutes before starting the engine.

Usually conditions of the valve steam and piston rods give a fair indication of the condition of the inside of the cylinder, i. e., a well lubricated piston rod means a well lubricated cylinder, while the reverse is also true. These indications are not always true when the swabs are kept in good condition.

Feed the same amount of oil to the valves of the superheater as fed on the saturated engine. In addition feed one drop to the cylinders for each four drops fed to the valves.

The use of cylinder oil is recommended for valves, cylinders and on swabs.

There should be no trouble with lubrication if the preceding instructions are followed.

FIRING

The firing should be such as to produce a bright, white fire; light and regular firing will usually give this result.

A dull or smoky fire has a lower temperature than a white fire and produces a lower degree of superheat. This means that to handle a given tonnage more time, labor, coal and water are required than where the fire is white.

MAINTENANCE AND REPAIRS

FLUES

In maintaining the large flues that are not welded it is essential that the flues fit the flue sheet at both ends closely the whole length of the sheet and in addition at the firebox end the flues should grip the sheet tightly between the bead and the prossering, so as to avoid any longitudinal movement of the flue in the sheet. This movement is sure to occur and means leaky flues, unless provided for as mentioned, because of the greater area of the flue in contact with the front flue sheet, due to its greater diameter.

This condition required that the rolls be discarded after the flue is first set and that the flue should be maintained or worked with the beading tool and prossers only at the firebox end.

After the prosser is used, the beads should always be worked lightly to make sure that the beads are tight against the sheet. A standard for beading tools should be adopted and all beading tools kept to that standard. A bead-tool with a radius of 5/32 inch and depth of bead in the tool 13/64 inch has been found satisfactory for superheater flues. In use, the centre line of the beading tool should always be kept inside the line of the flue.

TESTS

The superheater, steam and exhaust pipe joints and dry pipe joint should be tested periodically every thirty days, if convenient, at the time of the regular washout, with at least one hundred pounds of water pressure, preferably hot, if the engine is warm.

The test can be applied through the blow-off or point usually used for filling boilers, or through the cylinder cocks or port plugs as explained in the chapter on Locomotive Front Ends. The dry pipe joints, steam pipe joints, joints between the units and the header, joints between the exhaust stand and cylinder, the exhaust stand and nozzle tip, and all seams and flues in the front end should be carefully inspected while under pressure to see that there is no leakage. The return bends at the back end of the unit in the large flue should also be inspected for leaks and any water laying in the bottom of the flue, under the unit ends, should be considered as an indication of unit leakage.

It is not uncommon to find serious leaks in the front end without a steam failure or poor steaming being reported.

Steam leaks from the flues, flue sheet seams, rivets, units, dry and steam pipe joints are all liable to cut into adjacent parts and cause serious damage, so that the tests should be carried out regularly and thoroughly.

LEAKING UNITS

Leaking unit joints next to the header should be stopped by tightening clamp bolt nuts, taking care not to stretch bolts. If this will not tighten the joint, remove the nuts on the clamp bolt, drop the clamp and slide the unit out so as to get at the joints.

Leaking dry, steam and exhaust stand pipe joints should be treated the same as on saturated engines.

All units with cast steel return bends should be tested to 250 lbs. hydrostatic test and should be tested to that pressure before installed in the engine, when any work has been done affecting the return bend joints or on any indication of leakage in the unit itself. A test of 500 pounds should be applied to units with the welded return bends under the same conditions.

CYLINDER AND VALVE PACKING RINGS AND VALVE BUSHINGS

A good grade of cylinder iron should be used for all these parts.

In practice the ordinary snap ring for the cylinder has given excellent service. This ring should be fitted to the cylinder with ⅛ inch clearance between the ends of the packing for cylinders of 21 inches and under, and 3/16 inch for cylinders over 21 inches. One-eighth inch to ¼ inch and more spring is given to the rings in turning them, the amount depending on the character of the material.

The rings when placed in the cylinder should be a close fit to the walls of the cylinder all the way around. If necessary, they should be turned or at least fitted until they do.

The L type rings for valve bushings are ordinarily given a spring of about 1/16 inch. They are applied with about 1/16 inch scant between the ends of the rings and should fit the valve bushings tightly all the way around and the ends travel over the centre of the wide bridge at the bottom.

The valve bushings should be applied with a wide bridge at the bottom and finished and bored in their place in the steam chest.

If the piston heads, cylinder heads, steam chest valve and rings and passage between the steam chest and cylinder and the exhaust stand pipe and tip are found to be gummed up or covered with "carbonized" material, it is an indication that the oil is not going into the steam or emulsion, but in drops improperly distributed in the steam, or that too much oil is used, or that the engineer is handling his engine without enough steam in drifting. The matter should be reported to the traveling engineer and should be taken care of from that end; the roundhouse and shops can do nothing in this matter except to keep the passages clean and the rings free in the valve and piston heads.

MAINTENANCE OF DAMPERS

In the process of superheating, the saturated steam from the locomotive boiler passes through pipes which are receiving heat from that portion of the firebox gases which pass through the large superheater flues. When the throttle is closed there is no steam passing through the superheater pipes, and consequently nothing to absorb this heat from them. Naturally such a condition would soon result in damage to the pipes from overheating. To prevent this, means have to be devised to prevent gases passing through the large flues when the throttle is closed. This is accomplished by partitioning off the large flues at the front end and providing at the bottom of the enclosure thus formed a damper which will automatically permit the gases to flow through the large flues when the throttle is open and there is steam passing through the superheater pipes, and prevent their passage when the throttle is closed and there is, therefore, no steam in the pipes.

CONSTRUCTION AND OPERATION OF THE DAMPER

The damper is supported by shafts having bearings bolted to the sides of the smoke-box. At one end the shaft extends through the smoke-box, and is keyed to an arm carrying a counterweight at the extreme end, the purpose of which is to bring the damper to a closed position when the throttle is closed. Between the damper shaft and the counterweight is located a bearing. One end of the damper shaft link is connected to this bearing, the other end being connected to the outside damper cylinder arm. This arm is keyed and pinned to a shaft to which is also connected the inside damper cylinder arm, which is operated by a piston in the damper cylinder. The damper cylinder is in communication with the steam pipe, or steam chest of the locomotive, through a steam pipe which is always open. When the engine throttle is open and pressure is built up in the steam pipes, this pressure is carried to the damper cylinder and actuates its piston. This piston in turn moves the connected parts described above, and opens the damper.

EFFECTS OF IMPROPER INSTALLATION OR MAINTENANCE

It will be evident, from a little study of the illustra-

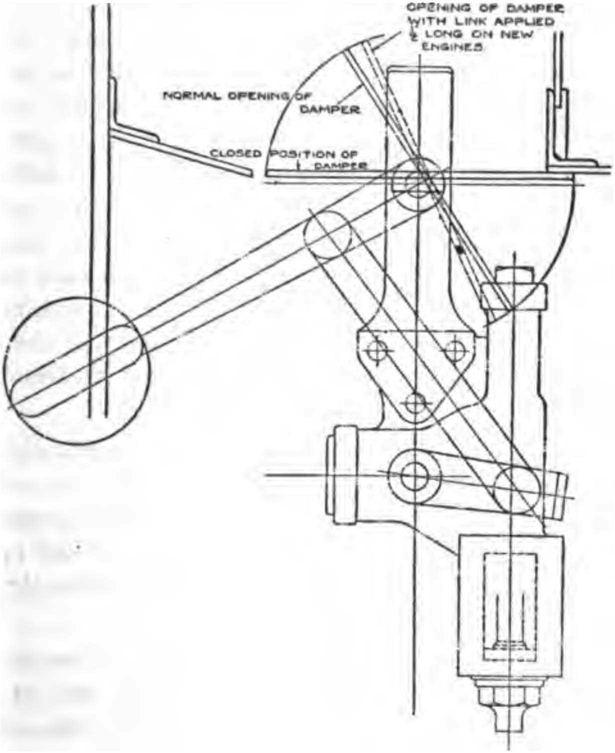

OPENING OF DAMPER WITH LINK APPLIED ½ LONG ON NEW ENGINES
NORMAL OPENING OF DAMPER
CLOSED POSITION OF DAMPER

Fig. 24. Damper Conditions with Link ½ in. Long

tions, that improper installation of the damper or its connections is liable to defeat the purpose for which the mechanism is intended. If the damper fails to close properly it will not effectually prevent hot gases entering the large flues when the throttle is closed;

Fig. 24 illustrates a condition which sometimes obtains after reassembling a damper rigging, which has been removed to undergo repairs. In reassembling, a damper link one inch longer than the standard has been used, the cylinder arm and shaft arm having been properly located. The effect of this is to prevent the damper from coming to its normal closed position, thus permitting a flow of gas through the large flues even with the throttle closed. In addition, the link will strike against the head of the damper shaft arm, preventing the full stroke of the damper cylinder piston which will not come to a seat on its ground bearing. In this case, the open position of the damper is not affected, but the results of the failure of the damper to come to a closed position are obvious.

Fig. 25 illustrates the results of the reapplication of a damper with the damper link two inches too short. The movement of the damper from closed to open position is now less than one-third of the normal opening and the passage of gases is very seriously restricted.

Lost motion is likely to occur between the end of the inside damper cylinder arm and the end of the slot in the piston rod, as illustrated in Fig. 26. This illustration also shows a convenient method of over-

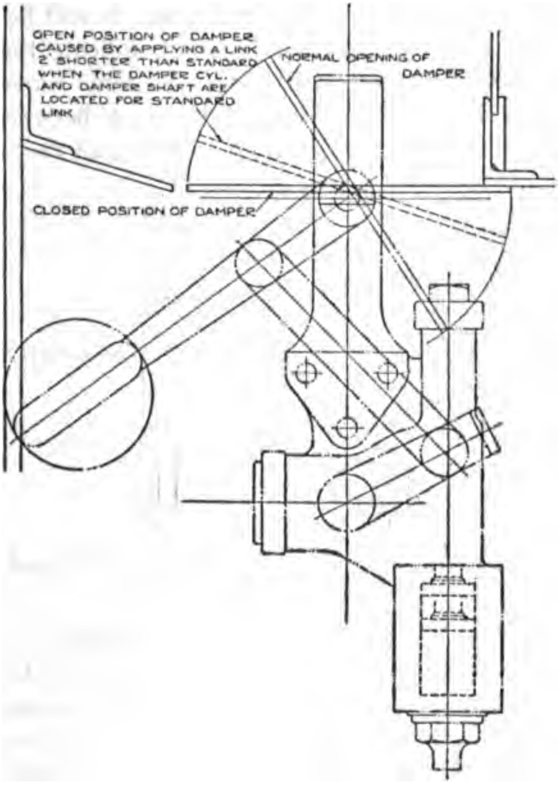

OPEN POSITION OF DAMPER CAUSED BY APPLYING A LINK 2" SHORTER THAN STANDARD WHEN THE DAMPER CYL. AND DAMPER SHAFT ARE LOCATED FOR STANDARD LINK
NORMAL OPENING OF DAMPER
CLOSED POSITION OF DAMPER

Fig. 25. **Damper Conditions with Link 2 in. Short.**

coming the effect of this wear by building up the end of the arm, and if necessary the slot, by means of oxy-acetylene or electric welding. It should be noted that the inside cylinder arm is not a tight fit in the piston rod slot, so that in testing a damper rigging for lost motion, the method should not be employed of lifting the counterweight and arm. It will be readily seen that this practice does not indicate the true lost motion, as there will always be some movement obtained in this way, due to the slack between the back or top of the inside cylinder arm and the slot.

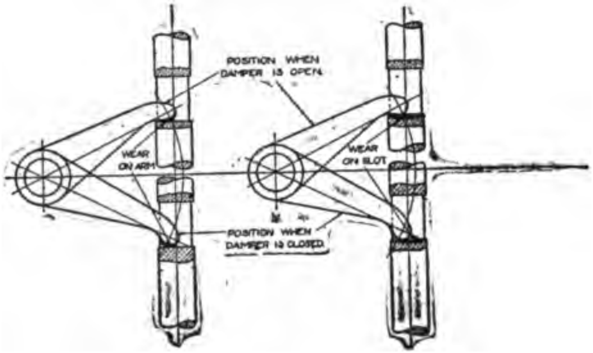


Fig. 26. Method of Repairing Worn Arm and Slot.

PREVENTION OF FREEZING

In cold weather, the damper cylinder may become inoperative due to moisture collecting and freezing in the steam and drain pipes, unless these are properly protected. Fig. 27 shows a desirable practice for arranging and lagging these pipes. Particular care should be taken to see that the pipes are so arranged that they will not contain pockets at any point which would permit moisture to collect and freeze.

The steam pipe should be ⅝ in. O. D. copper, 1/16 in. thick, and the drain pipe ½ in. standard iron pipe and both covered with lagging at least ¼ in. thick. The drain pipe should be connected at its lower end

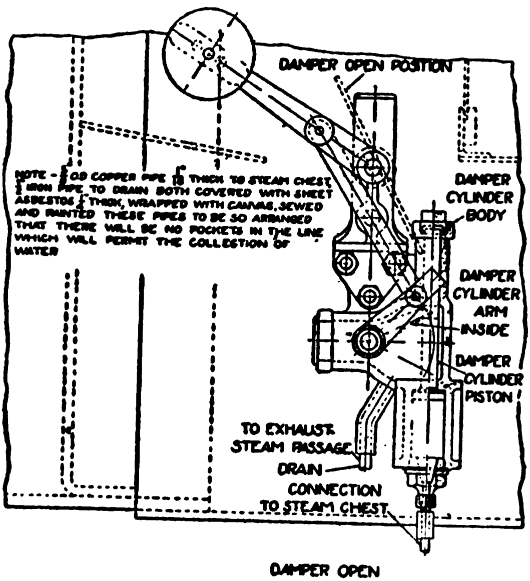
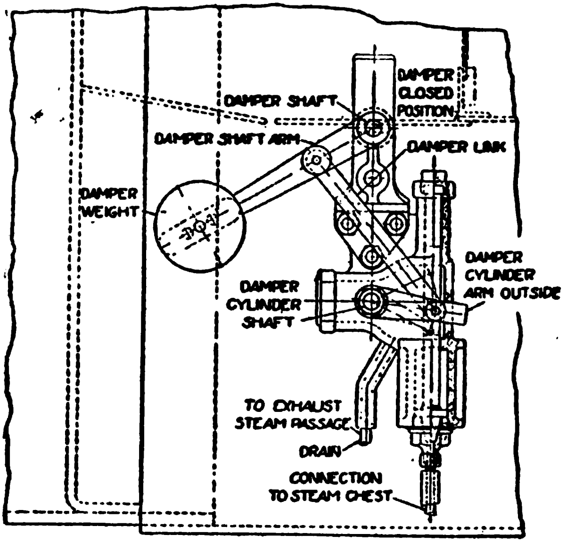

DAMPER OPEN POSITION
NOTE - [illegible] OD COPPER PIPE [illegible] THICK TO STEAM CHEST, [illegible] IRON PIPE TO DRAIN BOTH COVERED WITH SHEET ASBESTOS [illegible] THICK, WRAPPED WITH CANVAS, SEWED AND PAINTED THESE PIPES TO BE SO ARRANGED THAT THERE WILL BE NO POCKETS IN THE LINE WHICH WILL PERMIT THE COLLECTION OF WATER
DAMPER CYLINDER BODY
DAMPER CYLINDER ARM INSIDE
DAMPER CYLINDER PISTON
TO EXHAUST STEAM PASSAGE
DRAIN
CONNECTION TO STEAM CHEST
DAMPER OPEN

Fig. 27. General Arrangement of Damper Cylinder and Rigging and Method of Pipe Lagging.

to the cylinder saddle exhaust passage. The piston should always have a tight seat on the upper end of the cylinder when the damper is open in order to prevent leakage as far as possible.

Care should also be taken to connect the damper cylinder steam pipe above the oil supply pipe to the steam chest. If this connection is made below the oil pipe connection oil will be carried into the damper cylinder and is likely to so coat the piston and cylinder walls with gum and other deposits that the cylinder will become inoperative.



DAMPER CLOSED

Fig. 27 also shows the general arrangement of the damper rigging, with the cylinder shown partly in section so as clearly to indicate the relative positions of the various parts.

SWITCH ENGINE DAMPERS

In the case of switch engines, where the superheater units or pipes are not exposed to the same high temperature conditions for such long periods as they would be in road engines were no damper employed, or if the damper were open when the throttle is closed, the damper cylinder rigging is so arranged that the piston is operated by steam from the blower and the counterweight holds the damper open instead of closed. The damper is then open at all times except when the blower is in use. The mechanism is similar to that used on road engines, and is subject to the same conditions as regards wear and improper installation.

WHAT TO DO IN MAINTAINING DAMPERS

Maintain the damper cylinder and rigging so that the damper always closes tight and opens the required amount. Either too much or too little opening will have a bad effect on the steaming of the locomotive.

Keep the inside cylinder arm in its proper form, pins and pin holes so maintained that they will be free from lost motion.

Keep the steam and drain pipes well lagged and by welding on metal to take the place of that which wears off.

Keep the bearings well oiled at al times, and the protected from head winds.

Maintain a tight seat for the piston at the upper end of its stroke. Be sure the drain and steam pipes are the right size. (½ in. standard iron pipe size for the drain and ⅝ in. outside diameter copper pipe, 1/16 in. thick for the steam pipe.)

WHAT NOT TO DO IN MAINTAINING DAMPERS

If trouble is experienced with the damper mechanism, don't tie the damper open and continue to operate the engine in that condition, neglecting the necessary repairs.

Don't let a damper go without attention, if it is found to be opening either too much or too little.

Don't expect the damper mechanism to operate satisfactorily without oil on the bearings.

Don't permit lost motion in the bearings or pins.

Don't raise the damper shaft arm and counterweight by hand, and charge all the movement obtained to lost motion in the pins and pin holes. Some of it is due to the play between the inside cylinder arm and the slot in the piston rod.

Don't connect the steam and drain pipes so that they contain pockets and don't connect the steam pipe below the oil connection.

Don't fit up either the steam or the drain pipe without thoroughly lagging it.

MAINTENANCE AND OPERATION

HIGH WATER

Superheater units, through which the steam passes after it leaves the boiler and before it enters the cylinders, are located in large boiler flues so that they will come in immediate contact with the hot gases from the firebox and the STEAM will be superheated.

Water can be carried through the units just as readily as steam but WATER cannot be superheated. To be sure, much and possibly all of the water entering the units will be evaporated as it passes through. If, however, the superheater is used to evaporate water it becomes an auxiliary part of the boiler and cannot at the same time perform its intended function, that of superheating STEAM.

The economy of the superheater locomotive comes from highly superheating the steam and is proportional to the degree of superheat obtained. More coal is saved with 250° of superheat than with 200° or less. There is not so much water and coal used for each car handled. The engineer and fireman have a much easier time in getting over the division, even with increased rating and shortened schedule.

To obtain the best results from the superheated steam locomotive, carry the water at the minimum height demanded by conditions. Half a glass is better than a full glass, and less than half a glass is still better if conditions permit.

FLUE CLEANING

Highly superheated steam is essential to the maximum economy and capacity of the superheater locomotive, and clean flues are essential to the production of highly superheated steam.

The heat which is added to the steam in order to superheat it is absorbed through the superheater units from the hot gases as they pass through the large flues. If a superheater unit is shut off from these gases, the steam passes through it without being superheated. Every unit which is cut off from the action of the gases does its share in reducing the capacity of the superheater. One flue completely plugged in a 25 unit superheater makes 4% of the superheating surface inactive, together with the evaporating surface of the flue itself. The effect of several units thus cut off will very quickly show up in a falling off in the performance of the locomotive.

Flues can be kept thoroughly clean by blowing them out with compressed air from the firebox end. It is a simple operation and easily accomplished if it is made a matter of routine and done before the flues have become plugged. All accumulations of soot and cinders should be knocked off and blown through into the smoke-box. Honeycomb and slag should be removed from the ends of the units and taken out from the firebox end if too large to blow through the flues.

UNIT CLAMP BOLTS

In superheater locomotives the steam passes twice through the header. In the saturated state it passes from one compartment of the header to the units, where it becomes superheated, and returns from the units to the superheated compartment of the header, and thence to the cylinders. Each unit, therefore, has two joints with the header, and bearing in mind that these joints are all located in the smoke-box, the importance of their being always free from leaks will be evident.

Careful designing, based on experience, has provided a most satisfactory type of connection at this point. The units are made with ball shaped ends, which seat in 45° seats in the header, and are held in place by a clamp and a bolt for each unit. The bolts used are of heat-treated steel and have a tensile strength of 100,000 lbs. per square inch. Each bolt is fitted with two nuts capable of developing the full strength of the bolt.

With correct workmanship on the ball ends and header seats, these bolts insure tight joints at all times. Bolts of low tensile strength will stretch under the action of a workman with a wrench in setting up the nuts and the joints will not be steam tight.

UNIT BANDS AND SUPPORTS

The location of superheater units, when properly installed in the large flues, is such that each pipe will come in contact with its share of the hot gases and, at the same time, the unit will offer the least obstruction to the passage of the gases through the flues. It is also of the greatest importance that the pipes be held in their relative positions in the unit, and that the unit be held in place in the flue so that there will be no vibration.

All of these purposes are served by applying to the units bands and supports made of No. 14 B. W. G. steel, 2 inches wide. Each band and each support has a centre piece which, with the outer band, holds the pipes rigidly in position, and each support has riveted to it at the bottom two pieces of steel of square cross section so that the unit is held up from resting on the bottom of the flue and is in the correct location with regard to the distribution of the gases. A support acts as a band, as well as a support for the unit.

Only one band is applied to each unit. It is located on the unit 20 inches from the front end. One or more supports are used, depending on the length of the unit. This point should be carefully kept in mind in applying bands and supports when making repairs. If bands are used where supports should be, the unit will not be properly located in the flue but will rest on the bottom, so that all of the pipes will not receive their proper share of heat and such a location will tend to accumulate cinders and soot and plug the flue. Moreover, the unit would be free to vibrate in the flue and possibly cause serious results.

Bands and supports constitute an important, yet a simple, easily applied and easily maintained part of the superheater equipment. The correct application of the right number of each avoids the difficulties that would arise from units lying loosely in the flues.

LUBRICATION AND DRIFTING

It is well known that carbonization of oil in engine valves and cylinders destroys its lubrication qualities. A combination of air or oxygen and oil at a temperature above its flashing point is sure to be followed by carbonization. To prevent this combination, the throttle may be slightly open or "cracked" when the locomotive is drifting. By keeping steam in the cylinders at all times while the engine is in motion the intake of the products of combustion in the front end of the locomotive, which destroys the lubrication, is prevented.

The desirability of the use of oil capable of withstanding the high temperature of superheated steam in the valves and cylinders is indicated and its distribution both to valves and cylinders is recommended. Cylinder feeds tend to increase packing mileage.

Valve and cylinder rings should be turned, after they are cut, to fit the bore of the cylinder or steam chest. When they are turned larger than the bore of the cylinder or valve chambers and a piece is then cut out so they can be sprung into place they assume an oval shape and wear unevenly on the cylinder walls. Thereby a difficult lubrication situation is imposed at once which can be prevented by making the rings fit the walls closely but not too tightly, and using material of the best quality in both rings and bushings.

FRONT END AIR LEAKS

Air openings around outside steam pipes aggregating an area considerably larger than a two-inch hole are of common occurrence on locomotives operating every day on our railroads.

Air leaks in the front end waste fuel and affect the hauling power of the locomotive. The air entering the openings destroys the vacuum in the front end, thereby requiring reduction in exhaust nozzles to provide the necessary draft on the fire. The decreased exhaust nozzle opening adds to the back pressure in the cylinders, consequently reducing the tractive effort of the locomotive.

Parts of superheater locomotives which may affect economy should be very carefully watched for proper size and adjustment. Air openings in ash-pans on many locomotives are insufficient. Grate designs are not adaptable to the kind of fuel burned. Exhaust nozzle size and location bear a direct relation to fuel economy. Front end arrangement and adjustment, with special attention to the prevention of steam or air leaks, furnish opportunity for improvement in many cases. Stack design, size and location can be given closer attention with profitable results. Many other items might be enumerated, constituting things that it is more convenient to get along with than to correct, as the engine probably runs satisfactorily to those who do not have the owners' interests particularly at heart. Attention to them, however, would increase the earning power of the machine for the operators and move more freight.

THE PYROMETER

The pyrometer used on superheat engines is known as a thermo couple electric pyrometer.

When wires of two different metals are joined at one end and heated, an electric current will be formed between the free ends of the wires; the current passing through the wires is recorded on the milivoltmeter as degrees Fahrenheit.

The Pyrometer keeps a constant check on the engine's performance. If the fireman is not firing to the best advantage; if the engineman is carrying the water too high; if flues are filled up, or if the locomotive begins to fall off in its performance in almost any way, there will be a drop in the steam temperature which will at once be shown up by the pyrometer. On the other hand, when the superheater is function-ing properly and conditions are correct, the pyrometer will show normal steam temperature, The completed instrument makes use of the thermo-couple principle by means of which an electric current proportionate to the difference in temperature between the hot and cold junctures of the couple is generated The indicator itself contains a millivoltmeter actuated by the current generated at the thermo-couple and moves a pointer on the dial indicating the actual temperature of the steam.

The pyrometer equipment for each locomotive consists of three parts: a steam fixture (containing the hot junction of the thermo-couple), which screws into the steam pipe or steam chest of the engine; an indicator, which is placed in the cab, and a cable connecting the fixture to the indicator. The cold junction of the thermo-couple is at atmospheric temperature and variations in the atmospheric temperature are automatically compensated for. The hot junction of the thermo-couple is directly exposed to the flow of superheated steam and the slightest variation in the steam temperature immediately affects the current generated, showing this change instantaneously upon the dial in the cab.

The instrument meets all the requirements of a pyrometer for superheater locomotives and has been found valuable in checking operating and maintenance conditions indicated above, as well as proving a substantial aid in making adjustments and drafting locomotives.

The pyrometer has been used in foreign countries for many years in connection with superheated steam locomotives and, in fact, is considered as an essential a part of the locomotive equipment as the steam gauge itself. Many of the engine runners depend more completely upon the indications of the pyrometer for the operation of their locomotive than upon the steam gauge. Under the conditions of high-priced fuel and the demand for the ultimate economy and capacity from the locomotives in this country, the demand for suitable pyrometer equipment is increasing and the best results are to be obtained by equipping every locomotive with a pyrometer. The possible increase in fuel economy and capacity of the locomotive, by equipping every engine with a pyrometer makes the investment in pyrometer equipment negligible.

PYROMETER IN OPERATION

In making a terminal start, the pointer should move to the right rapidly until the temperature reaches about 400°; from this point on it should move less rapidly until the maximum temperature of from 600° to 700° is reached. It should be borne in mind that the rapidity with which the temperature increases depends to a great extent upon the height of the water in the boiler and the condition of the fire.

When the locomotive is working under average conditions, and a perceptible drop in the temperature is noted, some of the following defects, either in the operation or in the condition of the locomotive may be looked for:

The water level in the boiler may be too high and priming occur (water carried over into the superheater). The superheater then has to evaporate this water and consequently the final temperature of the steam is reduced.

The fire may not be in proper condition, due to heavy firing or the appearance of holes in the fire; either condition will reduce the firebox temperature and consequently the final temperature of the steam.

A portion, or all, of the superheater flues may be stopped up.

Air or steam leaks may be present in the front end; these will interfere with the drafting of the locomotive and prevent the free passage of gases through the large flues containing the superheater units.

The damper may not operate properly and interfere with the circulation of the gases through the flues.

Any one, or any combination of these defects, will cause a reduction in superheat.

The first two of these conditions can be prevented, or corrected, by the enginemen; the last three should be reported for attention at the terminal.

There are three parts to the instrument. (See Fig. No. 28.)

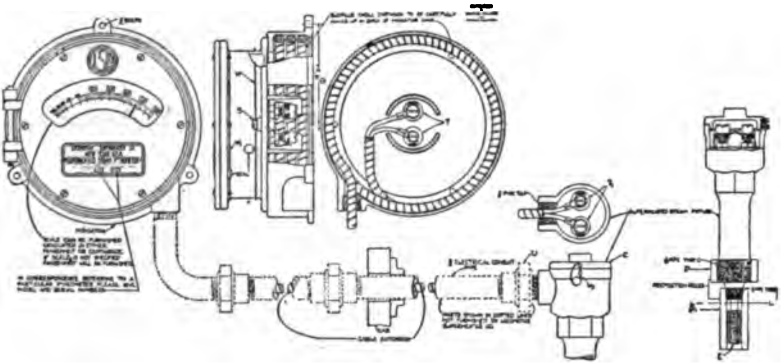


Fig. No. 28

Indicator
Steam Fixture
Cable Extension

The application of the pyrometer to a locomotive should be generally in accordance with Fig. 28.

The INDICATOR should be placed in a vertical position and attached to a rigid bracket. It should be in easy view of the engine crew. Three lugs are provided on the case for securing it to the bracket. The bracket should be firmly attached to the boiler and braced to prevent vibration.

The STEAM FIXTURE should be screwed steam tight into a 1¼" pipe tap hole (first removing the protecting pieces, P and P1), in the steam pipe just above the connection to the valve chest.

The CABLE EXTENSION should be installed in ¾" electrical conduit pipe and connected to the steam fixture and the indicator. The conduit pipe should be securely clamped and supported. Care should be exercised to see that there are no burrs left where the conduit pipe has been cut. The ends of the cable extension are interchangeable and the terminal eyes are of different sizes, so that it is not possible to connect the wrong terminals.

The wire must never be cut, but instead, in cases where the cable extension is too long the surplus wire should be coiled up in the space provided in the back of the indicator case, as shown in Fig. No. 28. After this has been done, and the terminals "T" connected in the back of the case, the case should be swung closed on its hinge and the screws "S" tightened. After these screws are tightened a wire "W" should be run through the holes, as shown in Fig. No. 28, and sealed. The seal on the wire "W" should never be broken. The cover "C" on the steam fixture should now be replaced and sealed with the wire "W_2."

Do not, under any circumstances, apply magneto test to any part of the instrument.

The pyrometer should have attention similar to that given to air and steam gauges. It should be tested, at frequent intervals, by a responsible man regularly assigned to the job, in order to find out if correct readings are being shown. To determine this the terminals "T" and the union "U" should be disconnected, the fixture removed from the steam pipe, the terminals "T" again connected and the end "E" of the steam fixture immersed in boiling water up to the line "L." When this is done the indicator pointer should show 212°, but the water must be actually boiling at the time the test is made. It will not be a satisfactory test to boil the water in a bucket or other vessel and carry it to the fixture, but the water must be kept boiling by the application of steam through a blower pipe or other means during the period of the test. If the pointer does not respond to heat applications the connections should all be examined to ascertain if they are in good condition, and if the defect cannot be found the pyrometer should be replaced by one known to be in good condition and the defective instrument reported to the manufacturer.

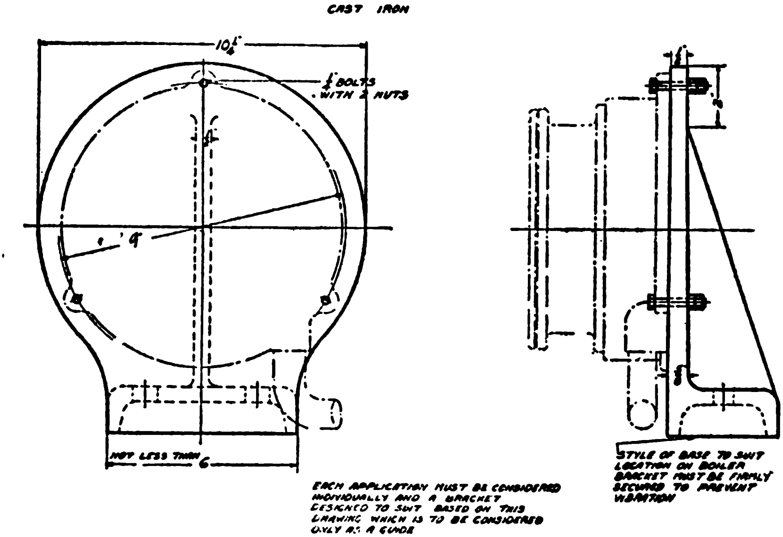

CAST IRON
10¼"
⅝" BOLTS WITH 2 NUTS
4"
NOT LESS THAN 6"
EACH APPLICATION MUST BE CONSIDERED INDIVIDUALLY AND A BRACKET DESIGNED TO SUIT BASED ON THIS DRAWING WHICH IS TO BE CONSIDERED ONLY AS A GUIDE
STYLE OF BASE TO SUIT LOCATION ON BOILER BRACKET MUST BE FIRMLY SECURED TO PREVENT VIBRATION

Fig. No. 29

LOCOMOTIVE BOILER APPLIANCES

INJECTORS

Let us assume that the boiler pressure is 180 pounds—that is to say, every square inch of the sheets, top and bottom, receives an internal pressure of 180 pounds. If a thermometer is placed inside, it is found that the surface water and the steam are at the same temperature, 379°. But the steam contains more heat than the water, because, after water is heated, more coal must be burned to break up the drops of water to change them into steam; this heat is stored in the steam and represents work done by the burning of the coal. Steam not only exerts a pressure of 180 pounds per square inch, but also can expand eight to twenty-six times its original volume, depending upon whether it exhausts into the air or into a partial vacuum; water under the same pressure would be discharged in a solid jet and without expansion. Either steam or water can be used in the cylinder of an engine or to drive the vanes of a steam or water turbine, but one pound of steam is capable of much more work than one pound weight of water, on account of the heat which has been used to change it into steam. This is easily seen by comparing the velocities of discharge from a steam nozzle and a water nozzle under 180 pounds pressure; steam would expand while issuing, reaching at the end of the nozzle a velocity of about 3600 feet per second, while the water, having no expansion, would have a velocity of only 164 feet per second, about 1/22 of that of the steam. The same weight of steam discharging per second would therefore have vastly more power for doing work than the water jet.

If a steam or water jet comes in contact with a body in front of it, the tendency is to drive the body forward. The force which tends to move the body is called "momentum," and is equal to the weight of water or steam discharged by the jet in one second multiplied by its velocity per second. If one pound of both the water and the steam are discharged per second, the "momentum" of the steam jet is 3600, because 1 multiplied by 3600 = 3600; the momentum of the water jet is 164. If the water jet discharged about twenty-two pounds per second, its momentum would be the same as that of the steam, because 22 multiplied by 164 is nearly 3600. The two jets are discharged under the same pressure, but the steam has twenty-two times as much "momentum" or force as the water jet; it could, therefore, easily enter a boiler at 180 pounds pressure if we could reduce it to the size of the hole of the water nozzle.

HOW OUGHT AN INJECTOR TO WORK?

Here a practical difficulty is reached. A steam jet 6 inches from the nozzle is much larger than at the opening, and it would appear almost impossible to make it enter a smaller tube. Even at the narrowest part of the nozzle it is more than sixteen times larger in diameter than a water jet discharging the same weight per second; therefore, if the steam is changed to water without reducing its velocity, it would pass through a hole one-sixteenth the diameter of the **"steam nozzle"** at a velocity of 3600 feet per second.

The simplest and best way to reduce its size is to condense it, and to use water for this purpose, especially as water is needed in the boiler. To condense the steam and utilize its velocity, the water must be brought into close contact with it, without interfering with the direct line of discharge; a funnel or **"combining tube"** suitably placed will compel water to enter evenly all around the steam jet. The mouth of this funnel must not be too large, or too much water will enter and swamp the jet; if too small, insufficient water will enter to condense the steam. The effect of condensing the steam is to reduce the diameter of the jet; therefore the funnel or combining tube must be a smooth, converging taper, to lead the combined jet of water and condensed steam into the smaller hole of the delivery tube. The effect of the impact of the steam is to give to the water its momentum, so that a solid stream shall issue from the lower end of the tube. Each little drop of entering water is driven ahead faster and faster by the vast number of little atoms of steam moving hundreds of times as rapidly, until the steam and water thoroughly combine into one swiftly moving jet of water and condensed steam, which contracts sufficiently in diameter to enter the smaller delivery tube.

WHY DOES THE JET ENTER THE BOILER?

The combined jet now passes from the end of the combining tube into the delivery tube; why does it enter the boiler?

If a pipe shaped like a fire-hose nozzle or a **"delivery tube"** is connected to a tank or boiler carrying 180 pounds, the water will issue in a solid jet with a velocity of about 164 feet per second, or, if we could force water into the tube at a speed of 164 feet per second at the same part of the tube, this water would enter and fill up the boiler or tank against 180 pounds pressure. Therefore, to enter the boiler the combined jet of water and steam issuing from the combining tube must have a velocity of at least 164 feet per second.

Now what is the velocity of the combined jet at the lower end of the combining tube? If the steam nozzle discharges one pound per second at 3600 feet velocity, the momentum of the steam is one multiplied by 3600, or 3600. If the vacuum caused by the condensation of the steam lifts and draws into the combining tube ten pounds of water per second at a velocity of forty feet, its momentum is 400; and that of the combined jet is 3600 added to 400, or 4000. The weight of the combined jet is eleven pounds, and at the time of entering the delivery tube its velocity ought to be equal to 4000 divided by 11, or 363 feet per second; but as the water and the steam do not meet in precisely the line of discharge there is a loss of momentum, and the velocity in the delivery tube is only 198 feet per second. But the jet only needs a velocity of 164 feet to enter the boiler or tank carrying 180 pounds pressure; therefore the actual jet in the delivery tube is able to overcome a pressure of 206 pounds per square inch, or twenty-six pounds above that of the steam, because the velocity of a jet of water under a head or pressure of 206 pounds would be 198 feet per second. This excess is more than sufficient to overcome the friction of the delivery piping and the resistance of the main check valve. Therefore,

"The action of the injector is due to the high velocity with which a jet of steam strikes the water entering the combining tube, imparting to it its momentum and forming with it during condensation a continuous jet of smaller diameter, having sufficient velocity to overcome the pressure of the boiler."

DEFINITIONS AND CLASSIFICATIONS

"Non-Lifting" and "Lifting."

Non-lifting injectors cannot raise the water which must therefore flow from the supply tank to the injector by gravity.

Lifting injectors both raise the water and force it into the boiler. They should be located just above the highest level of the water in the supply tank.

Injectors may further be subdivided into the following classes:

1. Single jet injectors containing a single set of nozzles.
    a. With central movable lifting nozzle attached to the operating lever.
    b. With an independent lifting arrangement.
2. Restarting injectors.
3. Double jet injectors containing two distinct and separate sets of nozzles for lifting and forcing.

The single jet injector with central lifting jet (Monitor type, 1888) has the advantage of simplicity of construction and operation.

Capacity

The capacity of an injector is measured in gallons of water per hour that it can deliver to the boiler at a certain pressure and under certain conditions of operation, the maximum capacity being the greatest volume or weight of water which can be discharged through the delivery nozzle at any given steam pressure and condition of feed, and the minimum capacity, the least volume or weight of water that can be continually delivered without waste through the overflow. This is often expressed as a percentage of the maximum capacity.

THE SELLERS INJECTORS
GENERAL DESCRIPTION

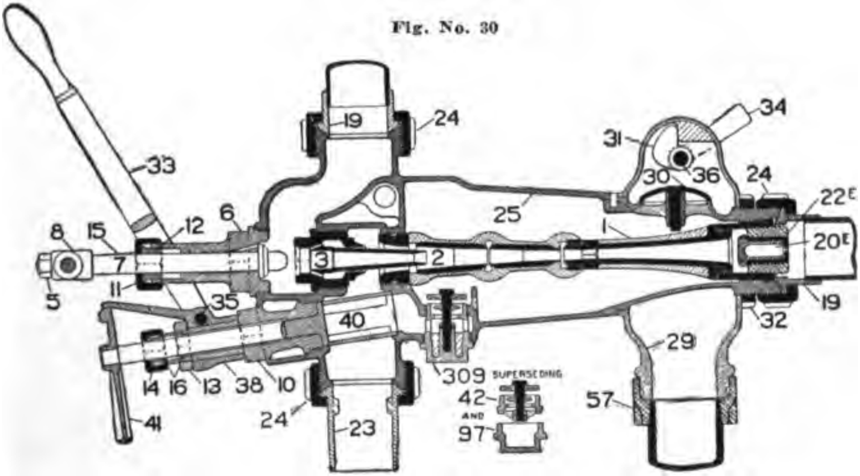
Lifting Forms, Class N Improved

The lever is used for starting only, and the water valve, for regulation of the delivery. All the valve seats that may need refacing can be removed; the body is not subject to wear.

The action is as follows: Steam from the boiler flows to the injector through (19); is admitted to the lifting nozzle by drawing the starting lever (33) about one inch, passes through the small diagonal-drilled holes in the steam nozzle (3) and discharges from the annular nozzle through the upper part of the combining tube (2) into the overflow chamber (25); it then lifts the overflow valve (30), and issues from the waste-pope (29). When the water is lifted, the starting lever (33) is drawn back, opening the forcing steam nozzle (3), and the full supply of steam discharges into the combining tube, forcing the water through the delivery tube into the boiler feed-pipe.

At high steam pressures the Improved Self-Acting Injector utilizes the vacuum in the overflow chamber (25) to draw an additional supply of water from the supply pipe through the automatically-opening inlet valve (309); this supplemental supply submerges the combining tube (2), and is absorbed by the jet and forced into the boiler, increasing the capacity about 20 per cent.

Fig. No. 30



The water-regulating valve (41) is only used to adjust the capacity to suit the needs of the boiler. The range is usually large.

To use a heater or to clean the strainer, the cam lever (34) is turned toward the steam pipe to prevent the opening of the overflow valve. The joint between the body (25) and the waste-pipe (29) is only subject to the exhaust pressure of the discharging steam and water while starting; the metal faces should be kept clean and the retaining nut (32) screwed up tight. To tighten up the gland of the steam spindle, push in the starting lever (33) to end of stroke; remove the little nut (5) and draw back the lever (33). This frees the crosshead (8) and links (15), which can be swung out of the way, and the follower (12) is tightened.

NON-LIFTING FORM

Improved Class N-L of 1908

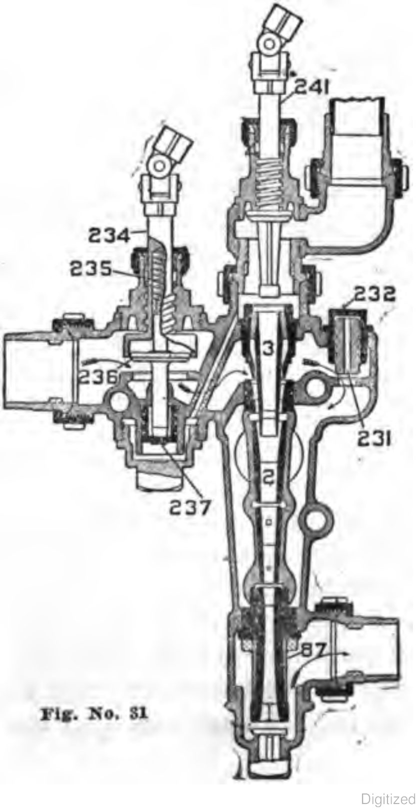


Fig. No. 31

This improved form of the non-lifting injector has the special self-acting features of the Class K, N-L, and in addition automatically stops the flow of water from the tank when the steam valve is closed. It thus has all the advantages of a lifting form, but is simpler to operate, contains fewer parts and is less affected by lime and scale in the water supply.

This feature is due to a patented Automatic Lazy Cock with internal steam connection. When the steam valve is opened, steam is admitted to the small piston (237) under the lazy cock; this raises the check valve (236) and water flows in the direction of the arrows into the injector. The Screw Lazy Cock (234) adjusts the feed and must not be closed when the feed is stopped. When the steam valve is closed, the pressure of the water, assisted by the spring (235), contained in the lazy cock stem (234), instantly closes the check valve (236) and prevents further overflow of water. Even when the Lazy Cock is wide open, water will not flow until the Steam Starting Valve is opened.

As the name Self-Acting implies, all the ordinary hand adjustments for restarting or regulating the feed supply to suit changing steam pressures are entirely dispensed with. All adjustments are automatic.

It is Restarting; that is, if the water supply is temporarily interrupted, the Injector will start automatically as soon as the supply is resumed.

It is Self Adjusting, requiring no regulation of the tank valve or lazy cock to prevent overflow when the steam pressure falls.

The N-L Injector of 1908 and the K, N-L, are provided with a patented balanced inlet valve. This valve gives an additional inflow of water to the tubes during the operation of the Injector, surrounding them with a bath of cold water direct from the water supply, reducing the formation of scale and largely increasing the capacity at high steam pressures, without affecting its action at low steam. This valve is balanced without the aid of a spring, and opens by the low pressure in the overflow chamber passing to the small chamber above the valve, raising it the required amount, and admitting a supplemental supply of water to the openings in the tubes.

NON-LIFTING FORM—CLASS K, N-L

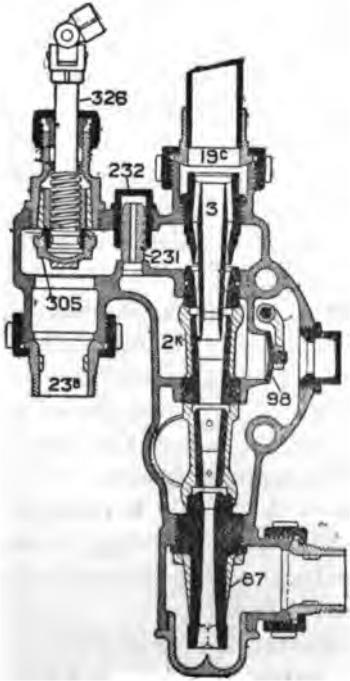


Fig. No. 32

This form is designed to operate under a head of water. Water flows through (23B) when the lazy cock (305) is opened; and by opening a lever or screw steam valve in the cab, steam is then admitted to pipe (19C). After a momentary spurt of water from the overflow, the jet passes through the combining tube (2K) and the delivery tube (87) into the boiler feed pipe. At high steam pressures the partial vacuum within the overflow chamber acting upon the larger area of the piston in the cap (232), lifts balanced inlet valve (231), admitting a supplemental supply of water to the overflow chamber; this increases the capacity and reduces the tendency to form scale.

When the temperature of the supply is above 106 degrees, boiler pressure 200 pounds, the overflow must be closed to prevent waste. The hot water valve (98) then closes automatically and separates the lower from the upper part of the combining tube (2K) and protects the moving jet at its most sensitive part from pressure of the accumulated overflow. The highest operating or breaking temperature is thus raised to 147 degrees with 200 pounds steam.

The tubes and other parts can be easily taken out for cleaning and repair, by unscrewing the cap at the lower end. The overflow valve is closed by a screw stem and extension rod from the cab as illustrated in Fig. 33.

This injector is restarting and self-adjusting as described in detail in the preceding page. These features render the injector dependable under all conditions, so that it is not necessary for the engineer to observe the waste pipe; for it does not waste water when starting or if the steam pressure falls.

THE NON-LIFTING TYPE is placed below the running board; on locomotives with wide fire boxes or when the cab is overcrowded with special operating devices, it is often difficult to place within the cab injectors of required capacity to fill the boiler. But it is necessary that the injectors be of the restarting type, designed so that there will be little or no waste when started, and without boiler pressure on the body or overflow valve.

The illustration shows the necessary appliances and the application of Sellers Non-Lifting Injector for locomotive service.

The STARTING VALVE may be connected to the turret by either iron or copper pipe and supplied with coupling unions at either or both ends or with inlet and outlet tapped for steam pipe. This valve is balanced so that it can be easily opened by the starting lever when carrying the highest locomotive steam pressure.

THE NON-LIFTING INJECTOR can be placed at almost any desired position below the bottom level of the water in the tank and within a reasonable limit; two pairs of universal joints supplied for fitting admit a wide angle of the rods conected to the operating handles.

THE OPERATING STAND is preferably placed close to the side frame of the cab and slightly in front of the cab seat. The weight of the operating handles and connecting rods is carried by springs so that there is no tendency to close the valves.

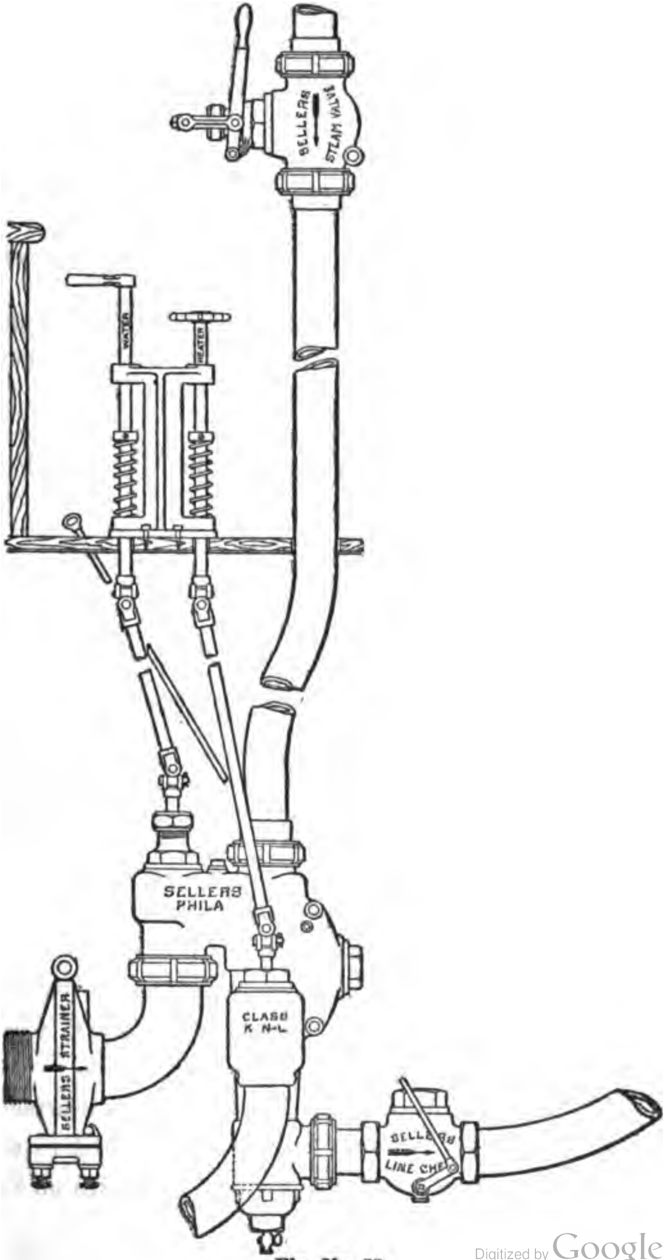

SELLERS
STEAM VALVE
WATER
HEATER
SELLERS
PHILA
STRAINER
SELLERS
CLASS
K N-L
SELLERS
LINE CHE

Fig. No. 33

THE FEED WATER STRAINER may be attached close to the Injector or to the union of the tank hose; the straining plate punched with ⅛ inch perforations and heavily reinforced may be removed without unscrewing the pipe joints.

THE LINE CHECK is guided by wings above and below the seat. It can be supplied with a drip operated by an extension rod from the cab.

DUPLEX TOP CHECK AND STOP VALVE

For Top of Boiler

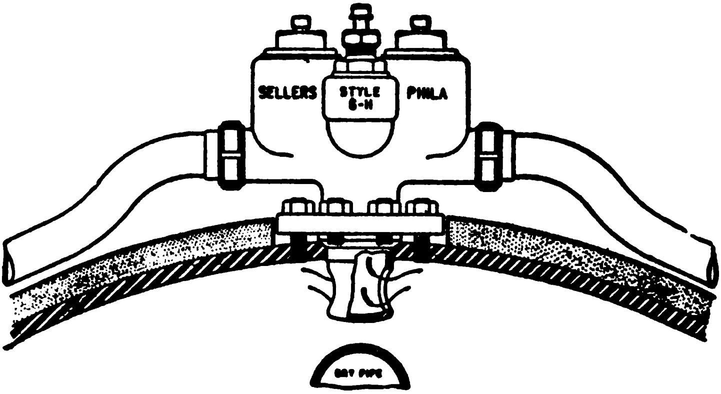


Fig. No. 34

Many railroads have found it advantageous to feed the locomotive boiler through the top sheet, when the water supply contains scale bearing salts.

The above illustration shows the method of attachment to the boiler; instead of a saddle bolted to the top sheet, by use of a ball joint provided with an extension which directs the flow of water laterally, preventing contact with the dry pipe.

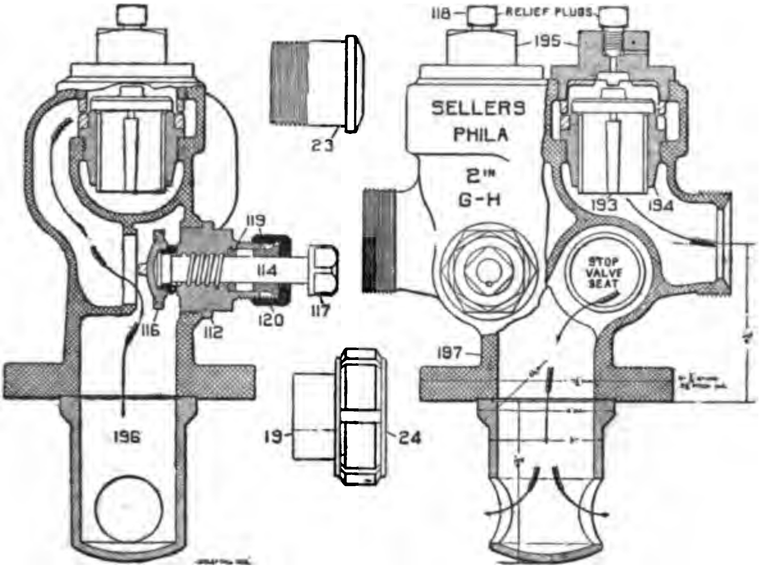


Fig. No. 35

COMBINED MAIN CHECK AND STOP VALVE

The main check valve and its seat can be removed from the body while the boiler is under pressure, as follows: close stop valve (116); open relief plug (118) one half turn, to relieve the pressure in the chamber between the stop valve and the main check valve (113); the main check valve and its seat (111) can then be removed for refacing and grinding. Can be applied to either the right or left-hand side of the boiler.

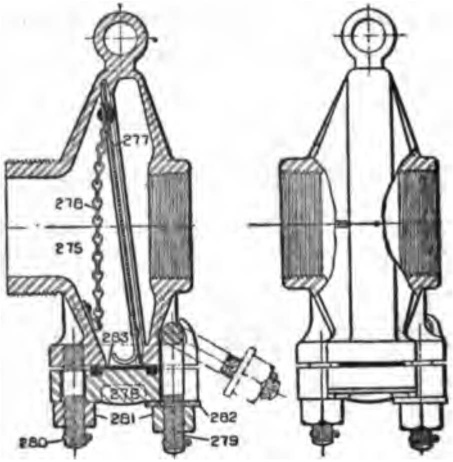


Fig. No. 26

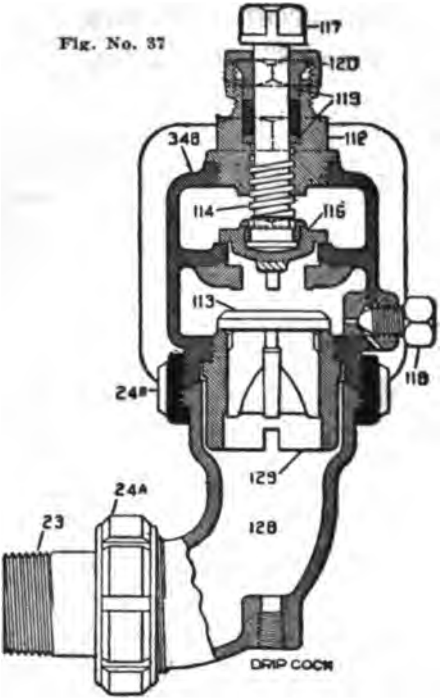
SELLERS LOCOMOTIVE FEED-WATER STRAINER

This feed-water strainer for locomotive use has shown in long-continued service tests many special advantages.

It has standard pipe or coupling nut connections, and is attached to the end of the injector suction pipe. It occupies little space, and can usually be applied without alteration of the length of the hose or of the pipe. The metal straining plate is of ample area, and is provided with holes so small that fine particles, which easily pass through the ordinary strainer, are kept out of the injector; the dirt trap is large, and admits considerable accumulation before cleaning is required.

The strainer can be cleaned in a few minutes with-

Fig. No. 37



out breaking the pipe or hose joint. The above figure gives a view from the under side, with the nuts slackened, the T head bolt swung upward, the cap rotated on the fixed stud clear of the opening, and the straining plate partially removed. The ends of the bolts are provided with split pins to prevent complete removal of the attaching nuts and washers, and their possible loss. All parts are strongly made—the body of bronze, and the straining plate of copper.

MONITOR INJECTOR

Type "R"—Description

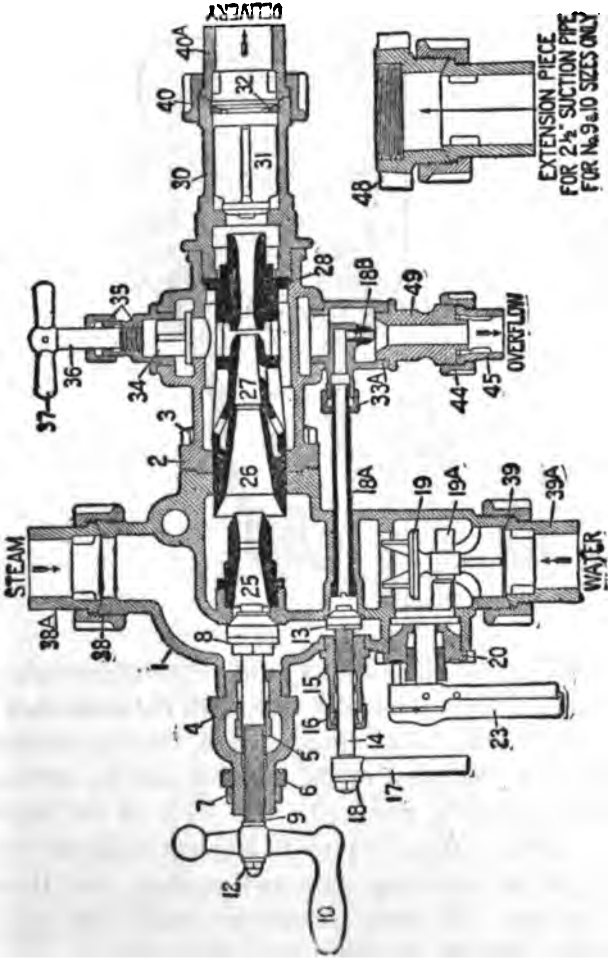


Fig. No. 43

The principal characteristic is the lifting jet, which, being independent and uninfluenced by any other part of the injector, enables it to make priming or starting reliable under adverse conditions.

The action is as follows: Valve 13 is opened first, which admits steam into the lifting tube 18-A and the lifting nozzle 18-B. The steam passing through the overflow nozzle 49, creates a vacuum in the injector body and suction pipe, which draws water from the tank into the body. This water passes through the heater cock check 34, chamber 33-A and nozzle 49. Valve 8 is then opened, which admits steam into the forcing steam nozzle 25, and mixing with the water, forces the same through nozzles 26, 27 and 28 and past the line check valve 31 into the boiler. It is necessary to open the valve 8 just sufficiently to deliver the water without waste at the overflow. The valve 13 is closed as soon as the delivery stream is established, and the quantity of water needed is regulated by means of the valve 19.

The heater cock check 34 should be open except when it is desired to warm the water in the tank. In that case, spindle 36 is screwed down on top of this check to keep it to its seat, and valve 8 is slightly opened.

SIMPLEX INJECTOR

Type "R"

It is simply constructed and contains only a few operating parts. It is self-regulating; that is, after being started at the highest operating pressure, the latter may drop down to about forty pounds before

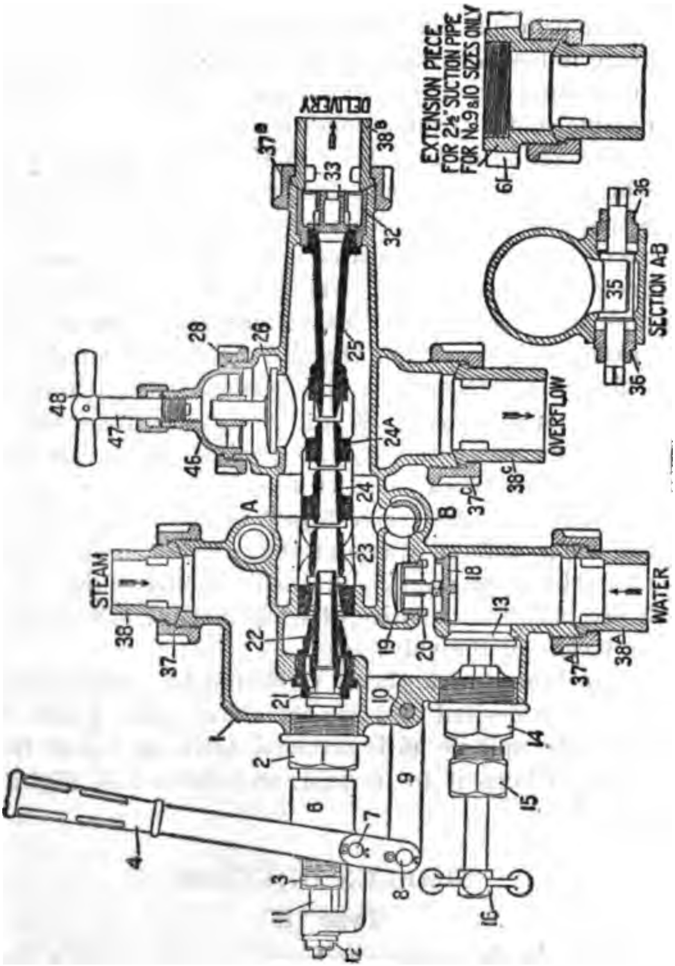


Fig. No. 44

there is any waste at the overflow. It is also restarting, that is, if from any cause the supply of water should be temporarily interrupted, the injector restarts automatically as soon as the water supply is restored. The reducing capacity is 50% of the maximum capacity under ordinary variations of lift and feed water temperatures.

The action is as follows: Steam from the boiler is admitted to the lifting nozzle 22 by drawing out the starting lever 4 slightly and without withdrawing the plug on the end of the steam spindle 11 from the steam nozzle 21. Steam then passes through the small openings around the steam nozzle, and discharges into the overflow chamber, lifts the heater cock check 26 and issues from the overflow to which the overflow pipe is attached.

When water appears at the overflow, the lever 4 is drawn back as far as it will go, which opens the steam nozzle 21 and allows the full supply of steam to enter the intermediate nozzle, forcing the water through the delivery nozzle 25 into the boiler.

At high steam pressure a vacuum is produced in the overflow chamber which draws an additional supply of water into the nozzles through the inlet valve 19, and through the supply openings between the nozzles, which additional water is forced into the boiler, thereby increasing the capacity of the injector under ordinary conditions of operation.

In other injectors provided with inlet valve, the injector does not prime properly, or not at all, if for some reason this valve leaks, but in the Simplex Injector the cut-out or emergency valve 35 is provided, which in such cases enables the inlet valve to be cut out and the injector to be operated until there is an opportunity to grind in or otherwise repair the defective valve.

The quantity of water needed is regulated by means of the water valve 13.

The heater cock check 26 is closed down only when it is desired to warm the water in the tank, in which case it is accomplished by the screw spindle 47. At all other times the heater cock check 26 must be allowed to open to its full extent.

NON-LIFTING SIMPLEX INJECTOR

Type "H-W"

(Flanged Connections)

This type of injector combines the qualities of the lifting Simplex instruments with simplicity of construction. The number of parts is reduced to a minimum, the injector consisting practically of a set of nozzles and a casing for holding same. Like the lifting injector of the Simplex type, this instrument is self-adjusting and restarting. It handles feed water as high as 125 degrees at 200 lbs. pressure and 145 degrees at 125 lbs. The water valve for regulating the quantity of water is part of the body, and is operated by means of a rod running into the cab for operating the overflow valve. Steam is admitted to the injector by means of a starting valve placed conveniently in the cab.

The action is as follows: Either the water valve or the overflow valve must be kept closed when the injector is not used, so as to prevent the water running out of the overflow. Assuming that the overflow valve is closed, then in starting, the overflow valve is opened first to let the water run through the injector, and then the starting valve is opened to its full extent. Steam then passes through the steam nozzles

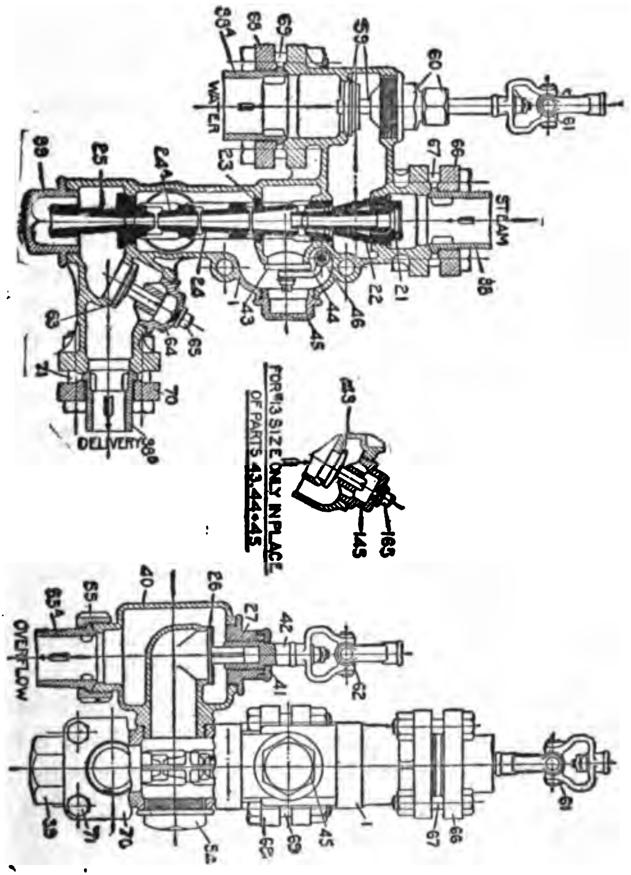


Fig. No. 45

21 and 22, meets and combines with the inflowing water in the nozzles 23, 24 and 24-A and forces the same through the delivery nozzle 25 into the boiler. In stopping, the operating valve in cab is closed, and then the overflow valve.

The quantity of water needed is regulated by means of water valve 59. The heater cock check 26 is to be open to its full extent except when it is desired to warm the water in the tank, in which case the overflow spindle 42 is screwed down, and the steam valve in the cab is slightly opened.

Part No. 43, which is hung to a hingle 44, is a non-return valve which permits the injector to operate with very warm feed water. If the feed water is warmer than the injector will take without spill at the overflow, then the overflow valve must be closed down after the injector has been started.

SIMPLEX 1918 SPECIAL A AND B

In its general characteristics, method of operation and results, this type of injector, which has been applied in large numbers on standardized Government engines, is the same as the type "H-W" Non-Lifting Simplex Injector.

The difference is that in the 1918 type the flanges are screwed on to the body in place of being cast on as in the "H-W" type. A further difference is offset to one side of the body and the top of the body is covered by the cap, part No. 2, so that by removing this cap, the steam nozzle of the injector may be taken out without disturbing any pipe connections.

This type of injector is also provided with a tell-tale arrangement consisting of a check valve, part No. 26, placed in the tell-tale elbow, part No. 25, and attached to the side cap, No. 24, on the body on the opposite side from the overflow chamber.

From this tell-tale a small pipe is run up into the cab, terminating in an elbow nozzle in front of the operator. The purpose of this arrangement is to indicate to the operator when the injector flies off for some reason that this occurrence took place and that the injector is not operating properly. When the injector flies off, part of the steam escaping through the overflow will escape through the tell-tale check and a small stream will be blown through the tell-tale nozzle, indicating the flying off of the injector. Thus warned, the operator will shut off the injector if the same does not start again automatically, provided that the flying off was caused by a temporary interruption of the water supply.

The action of the injector is as follows:

The water valve No. 10 of the injector being kept closed when the injector is at rest, this valve is opened first in starting so as to let the water run through the injector and then the starting valve in the cab is opened to its full extent. Steam then passes through the steam nozzles No. 3 and No. 4, meets and combines with the inflowing water in the nozzles No. 5, No. 6 and No. 7, and forces the same through the delivery nozzle No. 8 past the delivery check No. 31 into the boiler. In stopping, the operating valve in the cab is closed and then the water valve.

The quantity of water needed is regulated by means of water valve No. 10. The heater cock or overflow check No. 20 is to be opened to its full extent, except when it is desired to warm the water in

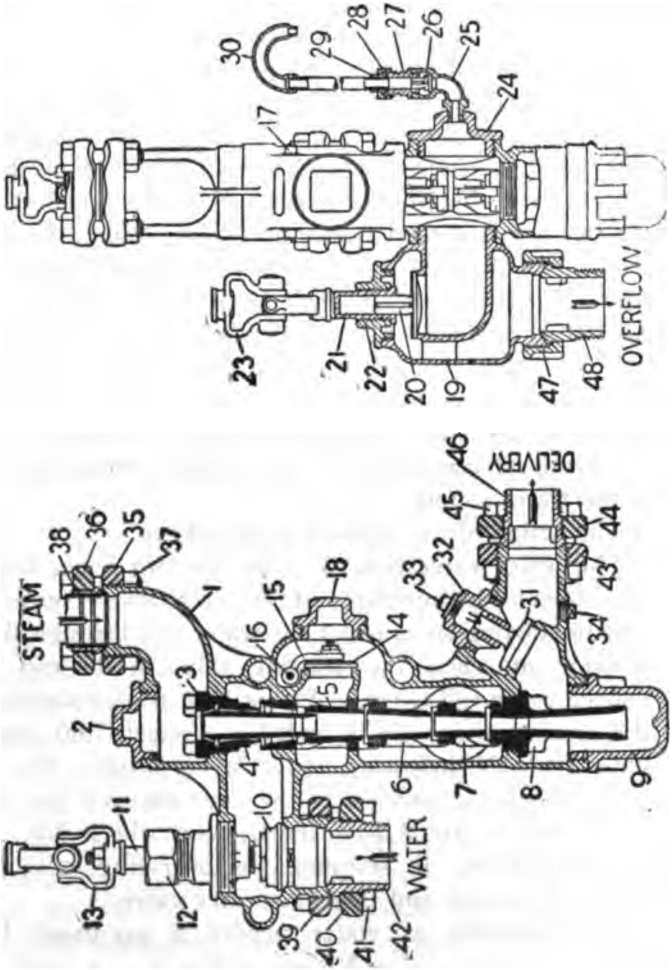


Fig. No. 46

the tank, in which case the overflow spindle No. 21 is screwed down to force the overflow check to its seat and then the operating valve in the cab is slightly opened.

If the feed water is warmer than the injector will take up without spill at the overflow, then the overflow valve must be closed down after the injector has been started.

APPLYING AN INJECTOR

All pipes should be blown out carefully with steam before the injector is attached, loosening the rust or scale by tapping the pipe with a hammer.

The valves should be kept tight, and spindles well packed. Leaky valves rapidly grow worse if not attended to, owing to the velocity with which steam passes through small openings.

Drip pipes attached to the overflow should not be of smaller size than the connections furnished with the injector.

Suction pipes must be absolutely tight, as air leaks reduce the capacity and prevent prompt priming.

Delivery pipes and boiler check valves must be of ample area, else undue friction is created and power wasted. For similar reasons all check valves must have the proper lift.

Suction pipes, hose and tank valve connections must be of ample size, and free from sharp bends and kinks.

Steam valves must not be forced hard against their seats, but closed and opened gently, otherwise the seats will wear out quickly. The delivery pipe may even burst if starting and stopping is effected with jerky movements.

Locate lifting injectors just above the high water level in tank. Do not place them unnecessarily high, as increasing lift decreases their efficiency.

Cold water in tank is best for these instruments. Warm water affects the lift and efficiency and reduces the capacity and lifting quality.

Strainers should be large enough to give an ample supply of water, even if a number of the holes in the strainer plate should be choked with leaves, cinders or other matter.

Scale should not be allowed to accumulate in any part of the injector, and particularly in and around the nozzle. To remove it, immerse the nozzles, or the whole injector, in a solution composed of ten parts of water to one part of muriatic acid. Take them out as soon as scale is dissolved.

Nozzles are the life of the injector. They must be maintained in good condition and their proportions must be correct to produce good results.

Repairs should be attended to promptly, and defects such as leaks, incrustation, etc., not be allowed to develop into serious ones. Checking the development of small defects lengthens the life of the injector and reduces the number of failures.

INJECTOR FAILURES

Injector Will Not Lift Water

This may be caused by any of the following defects:

1. Suction pipe stopped up.

This may be due to a clogged strainer, a collapsed hose lining or the pipe itself being clogged at some point. This naturally prevents the water from flowing readily through the pipe and is a frequent cause of the injector not priming properly.

In case the suction pipe itself is clogged, the remedy is to close the overflow valve and open the steam valve just sufficiently to blow steam back through the pipe and force out the obstruction.

In case the trouble is caused by a collapsed hose lining, the same remedy may be applied, and if it is not followed by good results the trouble may be overcome by turning the hose from end to end. The hose should have an easy curve from the tank connection to the suction pipe and should have no kinks in it as these reduce the area of the opening and obstruct the supply of water.

Any obstruction in the strainer may be removed by taking out the strainer waste plug and allowing some water to pass through, which will wash out the obstruction.

If the water pipe is provided with a strainer in the pipe itself and not accessible from the outside, the hose must be taken down and the strainer removed and cleaned. It is best, however, not to use any of these inaccessible strainers, but to have one either in the tank or between the hose and suction pipe which is accessible and can be cleaned without the breaking of joints.

2. Suction pipe or its joints leaking.

This allows air to enter into the pipe and prevents the formation of the necessary vacuum to lift the water. The suction pipe may be tested for leaks by closing the overflow valve and the tank valve, and then opening the steam valve just sufficiently to produce a slight pressure in the suction pipe and hose. The leaks will allow the steam to escape and indicate their location.

3. Water in the supply pipe or tank too hot.

This may be caused by a leaky steam valve in the injector, or by a leaky boiler check or line check-valve. The obvious remedy for this is to grind in the valves and re-seat them in addition, if necessary.

Injectors with hot water in the suction pipe may be started by closing down the overflow valve just long enough to blow steam back into the suction pipe and force the hot water back into the tank, then quickly open the overflow valve. Cool water then enters the suction pipe, replacing that which is hot.

In case the water in the tank has been heated to such a high temperature by blowing steam back into the tank to prevent the safety valve from blowing, or to warm the water in extremely cold weather, so that the injector does not prime, then the tank cover must be opened and, if possible, cold water added to cool off the hot water in the tank. It may be stated here that the injector handles warmer water at low pressure than at high pressure, so that should the water be too hot for the standard boiler pressure, the steam may be throttled down until the injector just barely starts with dry overflow, and so supplies water to the boiler at a reduced capacity until fresh cool water can be put into the tank and the temperature reduced.

4. Obstructed nozzles.

The openings between the condensing and delivery nozzles, and the spill openings in the condensing nozzle, may be obstructed by incrustation, preventing the ready exhaust of the air from the interior of the injector in starting. The remedy for this is to remove the nozzles and clean them. If they are badly incrusted they should be placed in a bath consisting of one part of muriatic acid to ten parts of water. Care should be taken that the nozzles are removed from the bath as soon as gas bubbles cease to be given off. As long as there is alkaline matter to combine with the acid, there is no danger of the metal being attacked, but after this is consumed, the acid attacks the nozzles, and the interior surfaces will be pitted and roughened, which affects the working of the injector.

THE INJECTOR LIFTS THE WATER, BUT DOES NOT FORCE IT INTO THE BOILER.

It may happen that the injector lifts the water, but does not force it into the boiler when the steam valve of the injector is opened, or it may force part of the water into the boiler and part of it out at the overflow. This may be due to any one of the following causes:

1. The suction pipe or strainer partly obstructed, hose lining collapsed, or a kink in the hose.

Under these conditions the injector does not lift sufficient water to condense the steam passing through the steam nozzle. The remedy for these conditions has already been pointed out.

2. The tank valve is partly closed.

This may be due to oversight or its handle may be so placed by mistake that the tank valve is closed when it is supposed to be open. The obvious remedy is to open the tank valve or put on the handle properly.

3. Too much or too little water being supplied to the injector for the prevailing pressure.

In case of too much water, the same issues from the overflow only slightly warm, and the remedy is to reduce the supply by means of water valve until the injector works properly and with dry overflow. In the case of too little water, the same issues from the overflow at a high temperature mixed with vapor. The remedy is to increase the supply of water or cut down the supply of steam until the injector works properly.

4. The delivery nozzle of the injector is cut, worn or obstructed.

In the event of the first two defects, replacement is the only remedy. The obstruction in this or in any other of the nozzles may be removed by taking out ot the steam valve, then inserting a piece of iron through the nozzles to break up the obstruction. If this cannot be accomplished, removal of the nozzles is necessary. Quite frequently it is found that a piece of coal or waste from the tank, or scale from the pipes, is carried into the nozzles, obstructing the passages just sufficiently to prevent the water from readily passing through. For this reason it is necessary that pipes, particularly steam pipes, be thoroughly blown out before they are connected up, and that the tank be kept clean.

5. Leaks in the suction pipe.

Leaks in the suction pipe may not be sufficient to prevent the injector from lifting the water, but the quantity passing into the injector may not be sufficient to condense all the steam, which has the effect of reducing or disturbing the vacuum in the combining tube.

Another effect of such leaks may be that the water in the combining tube not passing through in a solid stream is not properly acted on by the steam and the jet does not properly form. If the leaks are only slight, they simply have the effect of cutting down the capacity of the injector, and in such cases it works with a rumbling sound. How the suction pipe may be tested for leaks has already been pointed out.

6. Boiler check valve sticks.

If the boiler check is stuck entirely closed, the injector raises the water, but throws it out through the overflow and eventually breaks.

If the boiler check is stuck partly closed, then the injector puts some water into the boiler and throws some through the overflow.

In case the boiler check cannot be opened wide, the wasting of water may be stopped or reduced by cutting down the water supply to the injector and working it at a reduced capacity. The reduced supply may then pass through the partially opened boiler check without wasting at the overflow.

When the boiler check is stuck closed it may sometimes be opened by lightly tapping on the cap or on the casing of the boiler check, but this must be done carefully so that the casing will not be injured. Another method of opening the check which may succeed is to start the injector and gradually close down the water valve to diminish the supply of water and thereby increase the pressure which the steam exerts against the check.

If the boiler check sticks open and the line check valve does not prevent the water from flowing back from the boiler when the injector is shut off, it can sometimes be reseated by opening the frost cock in the delivery pipe or partially disconnecting the union of the delivery pipe and tapping lightly on the cap, or the casing of the valve.

If the chief defect cannot be remedied, then the overflow and the water valves of the injector should be shut to prevent the water flowing back from the boiler through the injector. The second injector must then be relied upon for feeding the boiler.

To find out whether a leak through the injector comes from a leaky steam valve or a leaky boiler check, the main steam valve of the injector, located on the boiler, should be closed. If it is the steam valve of the injector that is leaking, this stops the flow of steam at the overflow, but if the leak comes from the boiler check, steam and hot water continue to pass out at the overflow.

If the boiler check is provided with a stop valve, the communication between the boiler and the check valve may be closed, the cap over the check valve taken off, the check valve itself taken out and the obstruction which caused the sticking removed.

7. Delivery pipe frost cock opening too large.

In this event the delivery pressure may be so reduced that it is not sufficient to open the boiler check when waste at the overflow occurs.

8. Overflow valve leaking.

A leaking overflow draws air into the injector. If the leak is great enough, it diminishes the capacity of the injector and also disturbs the jet.

The remedy is the removal of the overflow cap and the grinding in of the check.

9. Tank cover too tight.

It is necessary that air freely enter the tank. If this is not the case, water from the tank is withdrawn by the injector faster than the air enters. The air in the tank expands as the water is withdrawn, and the pressure exerted by it diminishes. This may take effect to such a degree that injector does not receive the necessary supply of water, thus reducing its capacity, or breaking the injector. It is necessary, therefore, to see that the tank cover is not air tight.

Referring particularly to the Simplex Injector, Type "R," the inlet valve 19 may leak or be prevented from seating by some obstruction.

In that case the injector does not prime properly, or not at all. It is only necessary then to turn the emergency valve 35 around so that the letter "S" on the square spindle end is up. This cuts out valve 19 and permits the continued use of the injector until valve 19 can be repaired. Other injectors of similar construction not having the emergency valve feature become entirely inoperative if valve 19 should leak.

THE "KLINGER" REFLEX WATER GAUGE

The peculiarity of this type of gauge is that the water appears black, while the steam shines with a silvery lustre. This effect is produced by the peculiar shape of the observation glass, which has grooves cut into it, as shown in the illustration.

The Reflex Water Gauge consists of a metallic casing, which is made in two parts, No. 1 and No. 2 held together by means of the bolts No. 17 and No. 18. The glass part, No. 3, is held between the two parts of the casing. Packing gaskets are provided between the glass and the metallic casing. At the ends of the body stems No. 19 are provided, which enter the top and the bottom boiler fittings, which again are screwed into the boiler, in the proper location so that the lower reading of the glass will correspond with that of the lower gauge cock.

The advantage of the Reflex Gauge is the quick and reliable observation of the water level. It is a safety device, because the glass will not explode, and even if it should break, it will not fly out of the casing.

Referring to the table of sizes, it should be noted that the distances between the stuffing box nuts of the boiler valves indicates the minimum length within which a gauge of a given size may be placed. No larger gauges than those corresponding to the distances given between the stuffing box nuts can be placed within those distances, but smaller gauges may be so placed, provided that the sight lengths of the smaller gauge is sufficient for the proper indication of the water level. As a rule, the size of gauge corresponding to the given distances between the stuffing box nuts will be found to be the most suitable.

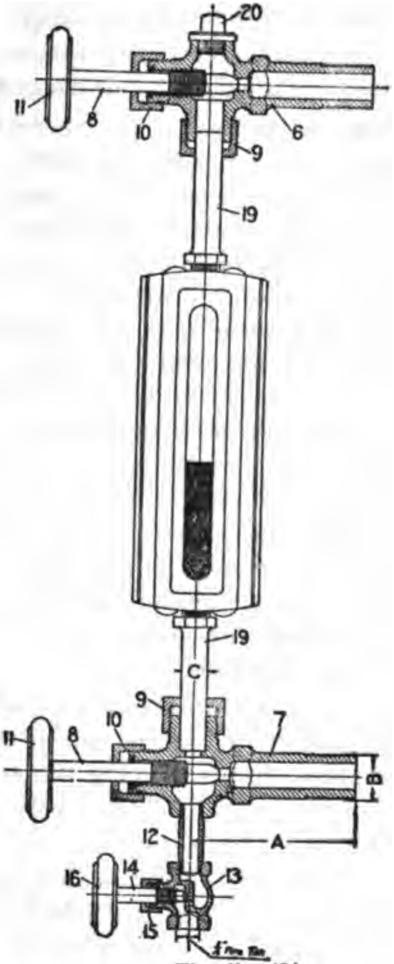


Fig. No. 47A

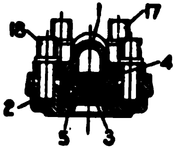


Fig. No. 47B

In applying the gauge, the stems at the two nuts are inserted into the boiler fittings in the same manner as is done with the ordinary gauge glass. In this connection it must be remembered that the thread at the gauge end of the stems is left-handed.

When putting on the gauge for the first time or after it has been off for repairs, the bolts should be followed up uniformly as soon as the gauge becomes hot, so as to take up any slack caused by expansion. This following up of the bolts must be repeated occasionally, as expansion and contraction is liable to loosen the joints and cause leaks, which must be prevented in order to preserve the glass in good condition. Never tighten up single bolts or bolts on one side only but tighten them all uniformly.

When a leak is noticed, do not allow it to grow, but take off the glass, clean the same and the joint faces of the casings thoroughly and renew the gaskets. The slight cost of proper gaskets will be more than balanced by prevention of annoyance and delay and leaks which cut and destroy the glass. Do not use over again worn or ragged gaskets.

Slight abrasions or cuts of the joint face of the glass will be first noticed on the steam end of the gauge. Reversing the glass, that is, placing the cut end on the water end of the gauge, will, as a rule, make the glass serviceable again for a time.

The gauges should be frequently blown out in order to get rid of mud or other matter which may injuriously affect the packing and the glass itself.

In a standard boiler mounting, the dimension "A" is 4" and the size of the thread "B" is of ¾" size. The diameter of the stem "C" is usually of ⅝" diameter.

THE HANCOCK INSPIRATOR

The Hancock Locomotive Inspirator is a double tube apparatus working with a positively closed final overflow valve. The inspirator consists of one apparatus for lifting or priming and another for forcing, each having its own steam nozzle and combining tube, so arranged that the lifter delivers the water to the forcer under pressure. This feature may be clearly seen by an inspection of the cut inserted herein.

The advantage of this construction exists in the automatic regulation or governing of the water supply. Both steam nozzles receive approximately the same steam pressure when the inspirator is working, the lifter tubes raising the water and delivering it under pressure into the intermediate chamber. The forcer receives this water and delivers it into the boiler. If the steam pressure rises, the lifter tubes will lift and deliver more water to the forcer, but inasmuch as there is correspondingly greater amount of steam passing through the forcer nozzle, proper care is taken of this increased supply of water.

As a result, the Hancock Inspirator has a range of steam pressure, working equally well at 35 or 350 pounds pressure without any adjustment.

In addition to this the receiving of water by the forcer side under pressure makes the inspirator much less susceptible to "breaking" under severe conditions, such as high suction temperatures or excessive back pressures.

The positively closed final overflow makes it impossible for any water to "spill" or be lost while in operation, thus insuring the delivery of all the water into the boiler. As the overflow nozzle is coupled to the overflow pipe, escapement of steam in the cab is avoided.

In principle, the lifting and non-lifting inspirators are precisely the same, the latter, however, is so designated that it works to best advantage when taking water under a head.

OPERATION OF THE HANCOCK INSPIRATOR

Lifting Type

To start the inspirator, pull back the lever No. 137 into the first or lifting position. This will draw the lifter valve No. 130 from its seat and admit steam through the forcer steam valve No. 126 to the lifter nozzle No. 101. The discharge of steam from this nozzle into the lifter combining tube No. 102 entrains the air in the suction pipe, finally producing sufficient vacuum to lift the water. The flow of water passes through both the intermediate overflow No. 121 and the forcer combining tube No. 104 and out of the final overflow No. 117. A further movement of the lever opens the forcer steam valve No. 126 and admits steam to the forcer steam nozzle No. 103, while at the same time the final overflow valve is approaching its seat, producing a consequent increase of pressure in the delivery chamber. This pressure closes the intermediate overflow valve and when the final overflow valve No. 117 is brought to its seat the inspirator will be in full operation.

The intermediate overflow valve operates automati-

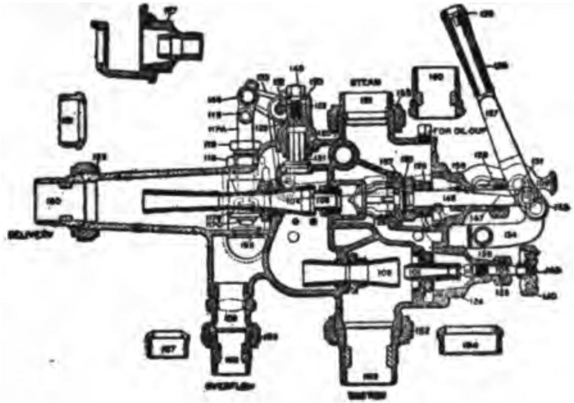


Fig. No. 40

cally and its function is to afford relief to the lifting portion of the apparatus when priming.

The variation in the capacity of the Hancock Inspirator is accomplished by means of the regulating valve No. 105. This valve reduces or increases the amount of steam admitted to the lifting nozzle of the apparatus.

To use as a heater, disengage the rod No. 106 from the stud in the lever No. 137 and pull it back until the final overflow valve is closed. The operating lever No. 137 is then pulled to the priming position, the amount of steam necessary for a heater being governed by the regulating valve No. 105. If desired, the operating lever No. 137 may be pulled back to its limit of travel, thus closing the final overflow valve; and the amount of steam necessary for a heater be adjusted at the throttle on the fountain.

POSSIBLE CAUSES OF INSPIRATOR FAILURES

Lifting Type

When an inspirator is reported "not working," be sure that the fountain valve and inspirator throttle valves are both wide open. Be sure that the inspirator is receiving a sufficient supply of water and that there are no leaks in the suction or syphon pipes. Before looking for trouble in the inspirator itself, be sure that there is no accumulation of lime in the overflow pipe, branch pipe, boiler checks or check shank to the boiler. About seventy-five per cent. of the troubles experienced are due to insufficient steam, insufficient water, leads in the suction, of restricted overflow or delivery.

When the inspirator refuses to lift or prime, after putting the lever into the lifting position, with the steam connections fully open and sufficient pressure on the boiler to operate the inspirator, the trouble may be due to one or more of the following causes:

A leaky suction, an obstructed tank valve, hose, hose strainer, suction or overflow pipe, a loosely fitting piston end of the forcer steam valve No. 126, a displaced lifter steam nozzle No. 101 or lifter tube No. 102 or an intermediate overflow valve No. 121 not free to work.

Improper Relation Between Final Overflow Valve No. 117 and Forcer Steam Valve No. 126

Too much lost motion in the connections between the lever No. 137 and the final overflow valve should not be permitted to accumulate, for it will disturb the relation between the forcer steam valve and the overflow valve which has been previously referred to. Temporary relief may be secured by screwing down the final overflow packing nut No. 118 to produce more friction on the stem of the overflow valve and prevent it from being suddenly slammed to its seat when near the point of closing. The proper course to pursue would be to have the inspirator removed and repaired so that the lost motion would no longer exist.

Intermediate Overflow Valve No. 121 Stuck Open or Leaking

If the foregoing tests do not result in the disclosure of the trouble and it is found that the inspirator still refuses to force water into the boiler, an examination of the intermediate overflow valve No. 121 should be made to see that it does not stick open or that there is no leak between this valve and its seat or between the removable seat and the body. If the inspirator goes to work, but gradually becomes weaker and finally breaks, it may safely be assumed that the intermediate overflow valve leaks.

If there is a leak of steam at the overflow when the inspirator is shut off it may be due to one or more of the following causes: A leaky lifter steam valve No. 130, a leaky forcer steam valve No. 126 or a leak between the latter's removable seat and the inspirator body.

If there is a leak of steam and water at the overflow the main steam valve on the fountain should be closed. If the leak continues it will indicate a leaky boiler check valve.

If water leaks from the overflow when the inspirator is at work the final overflow valve No. 117 should be reground and, if necessary, the removable seat made tight on its seat in the body.

After any or all of the possible causes of trouble have been investigated and remedied the inspirator should take water from the tank and continue to work until air begins to enter the suction when, of course, the inspirator will break.

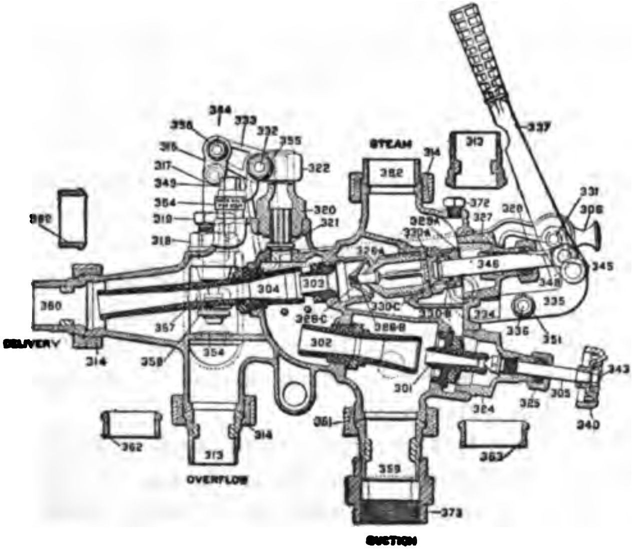


Fig. No. 41. Shows the latest Hancock Inspirator

THE HANCOCK NON-LIFTING INSPIRATOR

The internal parts of the Non-Lifting Inspirator are very much the same as those of the Lifting Inspirator, there is a lifter steam nozzle, a lifter tube, a forcer steam nozzle, a forcer combining tube and intermediate and final overflow valves. In addition to these parts which are contained in the body proper, there is an operating valve located in the cab and consists of a body, a lifter steam valve, a forcer steam valve, together with the necessary bonnet, packing nut, stem,

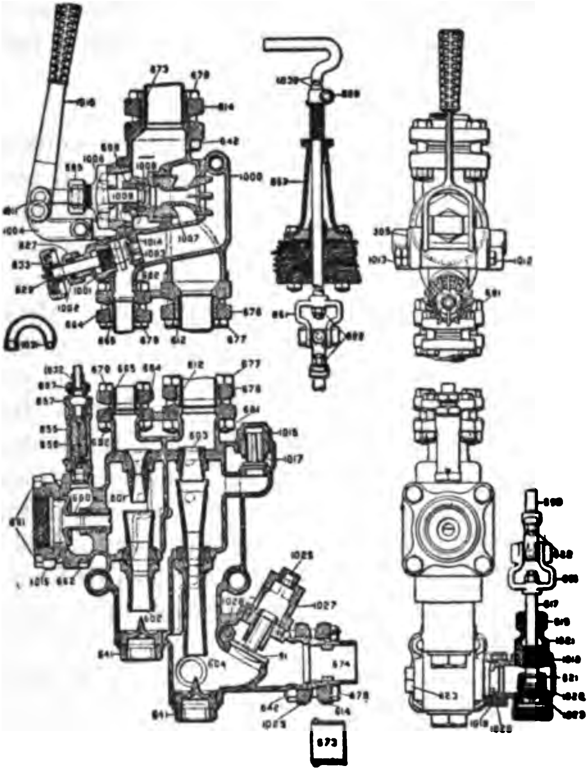


Fig. No. 42

lever and side straps, and also a regulating valve to govern the capacity of the inspirator.

In addition to the foregoing parts there is attached to the body of the inspirator a small valve called the "alarm," so designed as to open and, if the inspirator should break, blow steam through a small pipe leading up into the cab, thus giving warning to the engineer that the feed is interrupted. The open end of the pipe leading from the valve should be in full view of the engineer.

Operation

To start the inspirator under normal conditions, the regulating valve being well open, the final overflow valve should be opened by turning the handle about half a turn to the left (but when the inspirator is required to lift or dislodge hot water from the suction pipe the overflow valve should be opened to the fullest extent). Draw back the lever of the operating valve into the lifting or priming postion, the same as for a lifting inspirator, then draw the lever back as far as it will go and close the final overflow valve, whereupon the inspirator will be in full operation. By means of the regulating valve the capacity of the inspirator may be reduced to about thirty-three per cent. of its maximum. After very little practice it will be found that the drawing back of the operating valve lever and the closing of the final overflow valve may be performed almost simultaneously. Should the inspirator break or fail to work the fact will be indicated by the blowing of steam from the alarm pipe.

To Use as a Heater

With overflow valve closed, shut the regulating valve tightly and pull operating handle to priming position.

Repairing

Examine the steam nozzles and tubes and insert new ones if found necessary. Grind the intermediate and final overflow valves to their seats and also the lifter and forcer steam valves in the operating valve. See that there is a strainer in both the top and bottom of the alarm body to prevent the entrance of grit which might interfere with the operation of the valve.

Liming Out the Non-Lifter

To lime out the Non-Lifting Inspirator remove the cap No. 1016 above the intermediate overflow valve and the plug No. 641 underneath the lifter tube, leaving the intermediate overflow valve No. 1017 on its seat. Pour acid solution (1 part muriatic acid, 10 parts water) in on top of the intermediate overflow valve until it ceases to react and clear solution appears at the plug opening underneath the lifter tube, indicating that the lime has been removed. Next open the final overflow valve No. 1022 to draw off the acid and wash out the remaining acid by pouring water on top of the intermediate overflow valve, first closing the final overflow valve No. 1022. If the engine is under steam, replace the cap and plug and wash out the inspirator by priming.

Locomotive Safety Valves

Figs. 47, 48, 49, 50 show the present-day types of spring loaded safety valves.

The valve is held to the seat by means of a spring kept under tension by the compression screw equal to the desired steam pressure to be carried on the boiler. When the steam pressure on the boiler exceeds the spring pressure the valve will be lifted from the seat and steam will escape until such time as the pressure in the boiler is reduced below that of the spring when it will be seated against the remaining pressure.

Figs. 47, 48, 49, 50 show the construction of the Consolidated and Ashton safety valves used extentively in locomotive service.

THE CONSOLIDATED POP SAFETY VALVE

Forms R and S, although embodying the general construction of all Consolidated safety valves, are specially designed for railroad service. The former is plain encased and the latter is the muffler form. The construction is identical and all parts are interchangeable, excepting the two muffle shells which are added to the encased valve in making the muffler form. Hence the same repair parts and the same instructions for their use apply to each valve. In fact, a muffler valve can be converted into an encased valve by merely removing the muffle shells. When the muffle shells must be cleaned of lime or other sediment, it is not necessary to remove the valve from the locomotive or even to alter its adjustment. Instead, all that is necessary is to unscrew the outer muffle shell, lift both shells off and take them to the bench for cleaning. The removal may be made while the engine is under steam and as the valve will work perfectly without the shells, the engine need not be out of service on account of the removal of the shells. Trips may be made without them.

To adjust the valve it is only necessary to loosen the check nut a fraction of a turn, which can be ac-

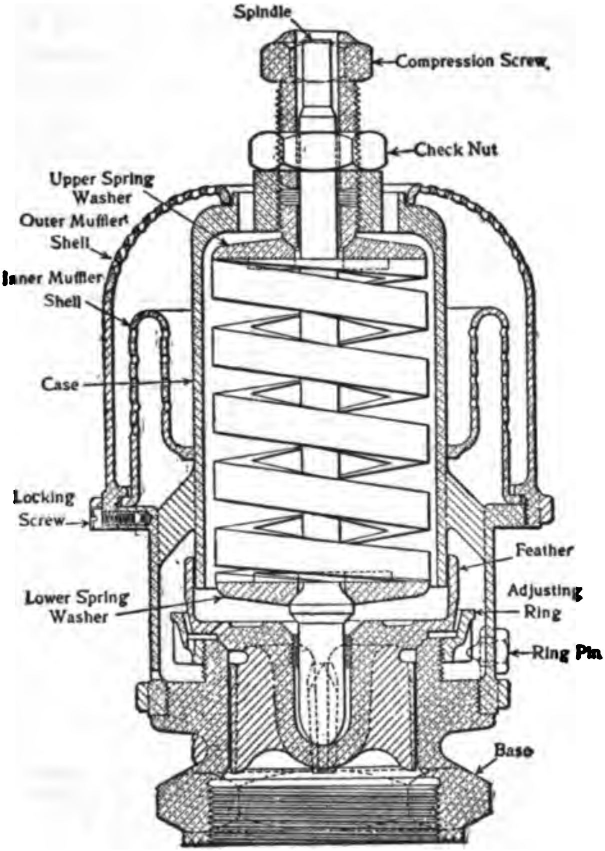


Fig. No. 47

complished without removing any of the parts. This nut cannot be lost or removed over the top of the compression screw, because the screw has a large heavy hex head. The threaded part of the screw above the check nut has been left exceptionally long, so as to be available for taking up wear. By placing the vent holes in the top of the case instead of at the side, the discharge of steam is all directly upward. There is no side blow—consequently the steam from a Consolidated Valve does not obstruct the view from the cab nor cloud the windows.

There are but twelve parts to the encased valve

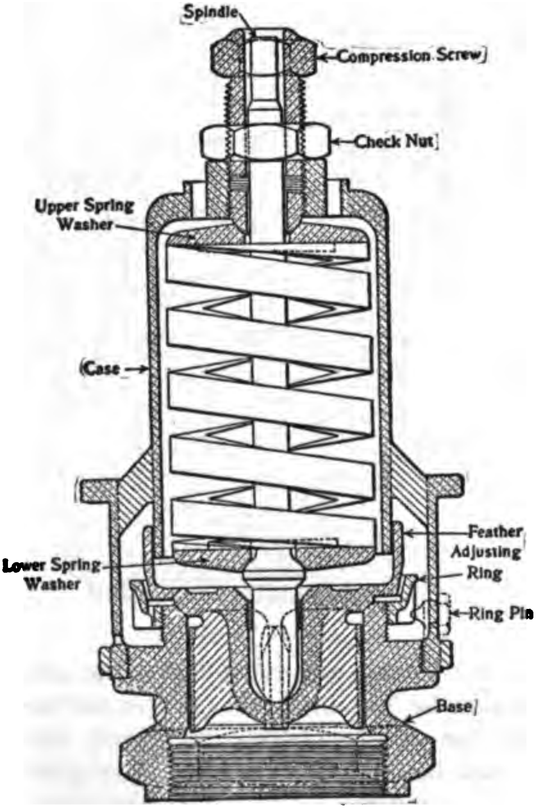


Fig. No. 48

Form R and but three more to the muffler Form S, a minimum number of parts in a safety valve, and all are so designed that repairs may be made quickly.

TO FREE FROM SCALE

If the holes in the muffle shells are filled with lime, scale or dirt, they should be thoroughly cleaned by scraping or by immersion in a suitable bath, the nature of which depends upon the kind of scale to be cut and dissolved. This operation can also be accomplished very quickly and economically by the use of sandblast. **All holes should be up to full area.** See that the drainage holes in the feather, adjusting ring, base, case and inner muffle shell are clean and free.

In many localities the nature of the water used is such as to deposit a scale on nearly all parts of the valve. If this makes it difficult to unscrew the various parts, soak the entire valve in kerosene or apply kerosene liberally to the joints thus affected, giving it time to penetrate. This obviates the necessity of excessive peining on any of the joints, which operation is liable to stretch the metal and unduly loosen the thread fits. All accumulation of scale on threaded parts should be removed by dissolving in suitable fluids and **not by chasing off the threads with a cutting tool.**

THE RICHARDSON ADJUSTING RING

Since George W. Richardson invented the first successful spring loaded safety valve—September 25, 1866—there never has been found any other means of adjusting the blowdown to equal the Richardson Adjusting Ring, with which the Consolidated Pop Safety Valve is provided. Though the principle of this, the original Pop Safety Valve, remains unchanged, many improvements in the application have been made since its introduction.

The action of the blow back. Referring to Fig. 48 it will be noticed the adjusting ring forms a small chamber at the base of the feather. When the valve opens the steam flows to the atmosphere following a path through the chamber like the capital letter N. For example, the steam must strike against feather, and be deflected down, then up; this gives a reaction against the feather, thus putting the pressure as a result of this reaction directly on the spring.

The adjusting ring is made with a bevel so as to increase the space as the valve raises.

Should the reaction produced by the ring be ten pounds against the spring the steam will be blown back this amount because of the extra pressure against the spring while the valve is open as compared with the valve closed. The blow back can be increased by moving the ring up nearer the feather, and reduced by lowering it.

THE ASHTON LOCOMOTIVE POP SAFETY VALVES

The Ashton Method of Pop Regulation from the outside of the valve body is positive, effective, and always operative. It requires no special wrenches or other devices to make any desired adjustment of the blow-back, and, being located at the top part of the valve body, is most readily accessible.

Ashton Open Pop Safety Valves

Style No. 28 M. M.

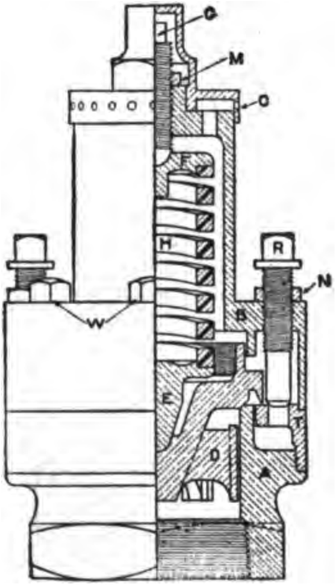


Fig. No. 49

The No. 28 M. M. (Master Mechanics) Open Pop Valve, above shown, has outside pop regulators, top discharge, and is of the bolted body type. It is constructed in accordance with the recommended practice of the Committee on Safety Valves of the American Railway Master Mechanics' Association of 1912, having hexagon of standard wrench size; standard pipe thread connection of same size as valve; .10 valve lift so stamped upon valve; and 45° seat.

The wing valves, springs, spring discs, caps, pressures crews, and lock nuts interchange in the several sizes with those of the No. 30 M. M. Muffler.

Ashton Muffled Pop Safety Valves

Style No. 30 M. M.

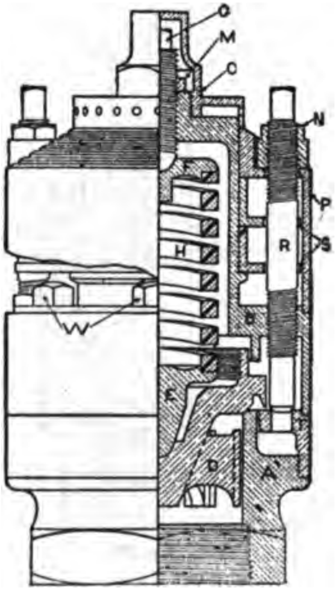


Fig. No. 50

No. 30 M. M. (Master Mechanics) Muffled Valve with outside pop regulators, bolted body type, connection standard pipe thread, same size as valve. Springs, spring discs, cap, wing valves, pressure screws, and lock nuts interchange with No. 28 M. M. Open Pop. Designed in accordance with recommended practice of the Committee on Safety Valves of the American Railway Master Mechanics' Association, 1912.

GENERAL INFORMATION ON SAFETY VALVES

POP SAFETY VALVES must always be applied close to the boiler. Their sensitive action requires close application to maintain constant pressure, and is necessary to keep them positive in action. Never use long nipples or connections with restricted openings, either of which will cause valves to chatter, due to momentary reduction of pressure.

HUMMING OR SINGING VALVES

The prevalent idea that a safety valve is working correctly when repeatedly opening and closing without reduction in pressure of two to three pounds is erroneous. This practice places the valve on a balance, producing rapid wear which soon results in a humming or singing valve. Destruction of valve can be prevented by pop regulators if adjustment is made at once. If allowed to run on a balance the wings will wear rapidly, seats and lip likewise, and the pop regulators will then have no influence.

Small openings into safety valve turrets are frequently the cause of safety valve trouble. (See Report of Safety Valve Committee American Railway Master Mechanics' Association, 1912, wherein it is recommended that such shall be equal to the combined area of the necessary safety valves.)

SAFETY VALVES should always be placed in vertical position.

SAFETY VALVE SPRINGS are made special for the size of valve and pressure. They cannot be used for a greater range than fifteen pounds above or below the pressure stamped on them without materially impairing the capacity and regulation of pop control. Lighter or heavier springs are required to be fitted for other changes of pressure. Interchanging of springs of various makes should be avoided, owing to the difference in valve construction and special steel used. Screwing down safety valve springs to make hydrostatic tests overloads the springs, subjecting them to a strain that may destroy their life and efficiency, and is also a dangerous practice. (See Report Safety Valve Committee American Railway Master Mechanics' Association, 1912.)

TO CHANGE "POP," slack check-nut on either one or both of the top regulators (numbered 2 and 3), and screw down for increased "pop," or contrary for less "pop."

NEVER CHANGE SET PRESSURE of a safety valve until gauge has been tested and found correct.

TO CHANGE SET PRESSURE, first remove top cap, thus exposing the pressure screw, then slack check-nut and turn pressure screw down for increased or upward for less pressure; afterwards set up check-nuts. When it is desired to change set pressure more than fifteen pounds above or below original set pressure, new springs should be ordered to obtain the greatest efficiency.

Valves must be repaired in such manner as to retain original lines.

Valve seats, 45°, 3/32 in. wide; 4 in., ⅛ in. wide.

Valve bottom should not be bored out. This practice increases the diameter of the valve, overloads the spring, and decreases the extended area of the lip on wing valve, which will prevent the valve popping as it should.

If valve wing is loose in body wings should be peined out, then turn up true with 45° seat and allow 1/100 in. diameter for expansion.

If necessary to turn up seat on valve bottom "A," take cut straight across face of valve seat and same amount off recess into which head fits. If this practice is not followed the repairing will eventually lower the wing valve below the top sleeve, which may prevent valve opening.

Before facing off seat on valve bottom "A" care should be taken to see that bottom is trued up with diameter and length of bore, not with the face of valve seat.

Do not turn off 1/16 in. if 1/64 in. will answer the purpose. Frequently the service of valves is shortened years by excess cuts.

Extended lip on wing valve must be within 1/100 in. of face of valve seat to obtain pop regulation and good results. Wing valve must rest solidly on the bevel seat **and slightly heavy on inside edge**; therefore the knife edge lip must never touch, otherwise the valve will leak. It is customary to carefully fit the valve when new so that the lip will have a space below it that will permit of a thin sheet of paper being passed between it and the flat seat, or so that the valve can be slightly rocked by hand.

After valve is repaired assemble without spring and see that the wing valve can be moved freely from its seat ¼ in. or more, and that the wings do not extend below pipe thread or strike the shoulder at end of thread where valve screws on to nipple.

Use graphite on bolts and pivot points of spring discs, also on dome nipple.

Pressure of springs stamped on outside of centre coil limit of variation, 15 lbs. over or under this pressure.

Springs showing a deflection of 3/8 in. or more from length as shown on illustration, or out of line 1/8 in. when measured parallel with the length, should be discarded.

Thoroughly clean out the turret or dome on boiler with air or water pressure before valves are applied, to prevent chips or foreign substances working into the valves.

Strong pop or blow-back is essential to efficiency. If valves are properly repaired pop regulators will control blow-back 0 to 10 lbs.; they are effective from a closed position for full pop to an elevation equal to their diameter for no pop.

Example for setting safety valves, locomotive boiler equipped with three valves, pressure, 200 lbs.:

3d valve set 205 lbs.; pop or blow-back, 5 lbs.; closes 200 lbs.

2d valve set 202 lbs.; pop or blow-back, 4 lbs.; closes 198 lbs.

1st valve set 200 lbs.; pop or blow-back, 3 lbs.; closes 197 lbs.

Always set and regulate pressure and blow-back on high valve first. Locomotives equipped with two valves use same formula. After setting valves at required pressure and when adjusting blow-back, should valve open a pound or two light, do not change the pressure adjustment; the repeated opening of the valve and flow of steam heats up the body and spring, and may cause a slight reduction in set pressure that will not accrue in regular service.

LOCOMOTIVE STEAM GAUGES

The steam pressure on a locomotive boiler is measured in pounds per square inch. For example: When a steam gauge shows 180 pounds it means that there is 180 pounds pressure on each square inch of inside area of the boiler.

The principle of operation is by means of a C-shaped tube made fast at the base, having one end made to move freely with suitable connections to a sector and spur gear attached to the pivot of the pointer. (See Fig. 51.)

When the pressure increases it tends to straighten the tube but this movement is passed back to the pivot of the pointer, causing it to rotate and move the hand to the pressure the gauge is designed to correctly register on the dial.

When the pressure drops the tube moves back to the curved position according to the amount the pressure has dropped.

The gauge must be kept cool; this is provided for by means of a syphon which will trap water. Will be explained further on.

ASHTON IMPROVED LOCOMOTIVE STEAM GAGES

Ashton Gages are carefully made and the product of the best material and skilled labor combined. They are made with solid drawn-brass seamless tubes. The movements are of solid construction and non-corrosive, having German silver pinions and arbors. Every dial is marked up separately and accurately to exactly match the mechanism of the gage on which it is used, and the letters and figures are deeply indented on all those of the silvered or black type and indelibly imprinted on the white enamel style, so they can be easily read and will not wear off. The springs are well seasoned to prevent setting.

ASHTON SINGLE SPRING PRESSURE GAGE

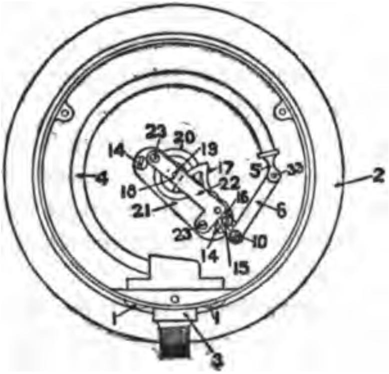


Fig. No. 51

The No. 51 Single Spring Gage is extensively used on railroads as the pressure gage on the steam heat system in coaches. It is also commonly used as the single air gage on locomotives and the regular standard style for stationary boilers. It is generally known as the Bourdon spring type.

List of Parts

1. Socket Screws
2. Case
3. Socket
4. Spring
5. Tip
6. Main Connection Arm
10. Connection Arm Screw
14. Screws Attaching Movement to Case.
15. Adjusting Slide Lock Screw
16. Adjusting Slide
17. Segment
18. Pinion (German Silver)
19. Bushing (German Silver)
20. Hair Spring
21. Bottom Movement Plate
22. Top Movement Plate
23. Screws holding movement together
24. Dial (not shown)
25. Ring (not shown)
26. Dial Screws (not shown)
27. Hand (not shown)
33. Tip Pin
34. Glass (not shown)

ASHTON IMPROVED LANE DOUBLE SPRING GAGE

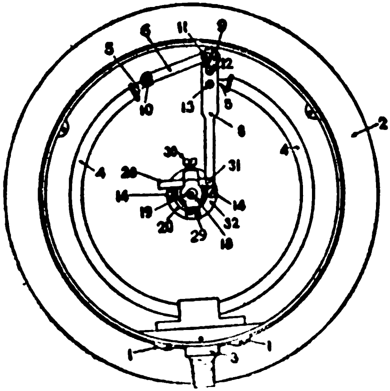


Fig. No. 52

It is made on the Lane Improved principle, with double spring of one piece solid drawn seamless tubing. For locomotive service it is superior to the single spring Bourdon gage, operating with less vibration on the hand, and consequently less wear on the movement. The shorter springs terminating at the top of the gage are self-draining, thereby preventing freezing up in case of exposure. The movement is fitted with non-corrosive German silver pinion and arbor. The threaded ring provided is a great convenience and time saver to shop men making repairs and adjustments. The hand-stamped silvered or black dial accurately matches each individual movement. The gages are made with O. G. or flush rings, silvered, black, or white enameled dials, and graduated to 300 or 400 lbs., or any specified maximum.

List of Parts

1. Socket Screws
2. Case
3. Socket (¼ in. pipe connection unless otherwise specified)
4. Spring
5. Tip
6. Main Connection Arm
8. Lever
9. Hub
10. Connection Arm Screw
11. Hub Screw
12. Lock Screw
13. Lever Connection Screw
14. Screws Attaching Movement to Case.
18. Pinion (German Silver)
19. Bushing (German Silver)
20. Hair Spring
24. Dial (not shown)
25. Ring (not shown)
26. Dial Screws (not shown)
27. Hand (not shown)
28. Rack (German Silver)
29. Bushing Screw
30. Rack Adjusting Screw
31. Rack Connection Screw
32. Movement Frame
34. Glass (not shown

GENERAL INFORMATION ON GAGES

STEAM GAGE CONNECTIONS should always be made direct to boiler shell and not to fountain head or pipes. The fluctuation of pressure therein will falsify the reading and injure the sensitive movement. Where the above practice cannot be followed, protect the gage movement by partially closing the stop cock until the hand ceases to vibrate, using care not to diminish the pressure on the gage in so doing.

STEAM GAGE SIPHONS. All steam gages must be protected by a siphon **filled with cold water** and of sufficient length to prevent heat reaching the gage tubes. Frequently gages are ruined by short siphons, turning steam into the gage without filling siphon with water, or leaky unions and connections, allowing the live steam to reach the tubes and anneal them.

LOCATION OF GAGES. It is essential that gages be protected from extreme heat and properly insulated from the boiler shell. Gages located over fire doors, or on top of large boilers with short space between boiler and cab roof, have been found sustaining a heat temperature of 200 degrees and, due to this heat, 20 lbs. fast.

TORCHES LAID UNDER STEAM GAGES, on the road and in round houses while firing up locomotives, are frequently the cause of gage trouble.

GAGE CASES STRAINED and movements injured are often the result of short connections and bolting gages up to irregular surfaces.

GAGE GRADUATION should be approximately twice the working pressure for satisfactory results and durability.

INTERCHANGING OF GAGE DIALS should be avoided as much as possible; dials are made up to the individual spring tubing and movements, therefore graduations vary on each dial.

SOLDERING OF TUBES cracked by frost, service, or defective material is poor practice. The solder destroys the elasticity of the tube, and gage so repaired cannot be accurate.

SIZE OF GAGES is determined by measuring across the dial, not the face ring or gage back.

SPECIAL INSTRUCTIONS ON CARE OF AND REPAIRS TO GAGES

USE GRAPHITE on all moving joints and gage rings where screwed on case; it will reduce friction and prevent wear. It is more satisfactory than oil, which attracts and holds dust.

GAGE SIPHONS. Always fill them with water before opening steam connection to gage.

UNIONS AND GAGE COCKS. Test them and see that they are in perfect condition; a leak in same may result in a gage failure.

LARGE WRENCHES should never be used in making up gage connections. The small connections require no long wrenches to make them tight, and the strain produced may injure the movement or break the sockets.

GAGE HANDS are a taper fit and should not be driven on with a large hammer. This practice frequently bends the arbor.

GAGE TAKE-UP. Gages are usually made with 2 to 5 lbs. take-up to prevent vibration wearing the movement and to hold the hand firmly against the stop-pin when the gage is not in service or when it is being handled in shipment; therefore the unequal spacing between the stop-pin and the first division or graduation mark. This take-up should be maintained and the small hair springs kept in good condition.

REDUCING VALVE APPLICATION. Gages

working in connection with a reducing valve should be graduated as high as the boiler pressure to protect it in case of reducing valve failure.

THE MASON LOCOMOTIVE REDUCING VALVE

The principle on which the Mason Reducing Valve works is that of an auxiliary valve 11, controlled by the low pressure in the heating system, through the medium of a metal diaphragm, and admits steam from the initial side of the valve through a port to operate a piston 17, which in turn opens the main valve 16 and admits steam to the system. See Fig. 53.

By referring to sectional view, it will be seen that the steam enters the valve at the side marked "inlet," a small portion of it passing up through the auxiliary valve 11. This valve 11 is forced open by the compression of the large spiral spring 8, acting on the button 10, through the diaphragm, so that, in opening the valve 11, the diaphragm is also forced down. As soon as the valve 11 is opened, steam passes through and into port N, under piston 17. By raising this piston 17, the main valve 16 is opened against the initial pressure, since the area of valve 16 is only one-half of that of piston 17. Steam is thus admitted to the system.

When the pressure in the system has reached the required point, which is determined by the spring 8, the diaphragm is forced upward by the low pressure, which passes up through port XX, to chamber OO, under the diaphragm, allowing valve 11 to close, shutting off the steam from piston 17. The main valve

16 is now forced to its seat by the initial pressure shutting off steam from the system and pushing the piston 17 down to the bottom of its stroke. The steam beneath this piston 17 exhausts freely around it (the piston being fitted loosely for this purpose) and passes off into the system. It will be seen from this that when the pressure in the heating system has reached a predetermined point, the flow of steam will be automatically checked, and when the pressure is slightly reduced, the valve will again open and supply the required amount of steam.

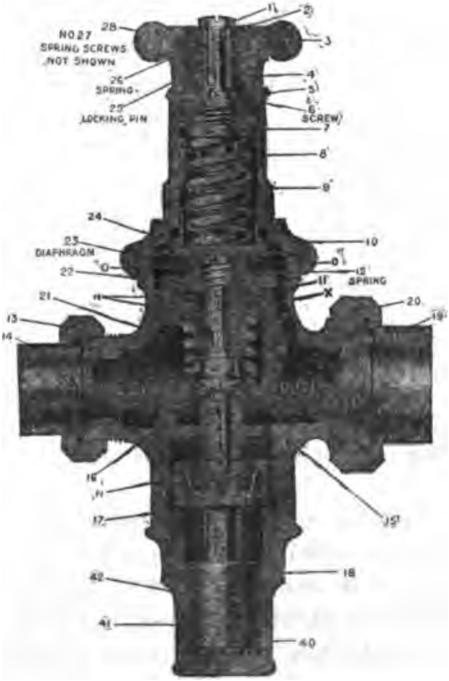


Fig. No. 53

The piston 17 is fitted with a dashpot 18 which prevents chattering or pounding when the pressure is suddenly reduced.

THE LESLIE STEAM HEAT REGULATOR

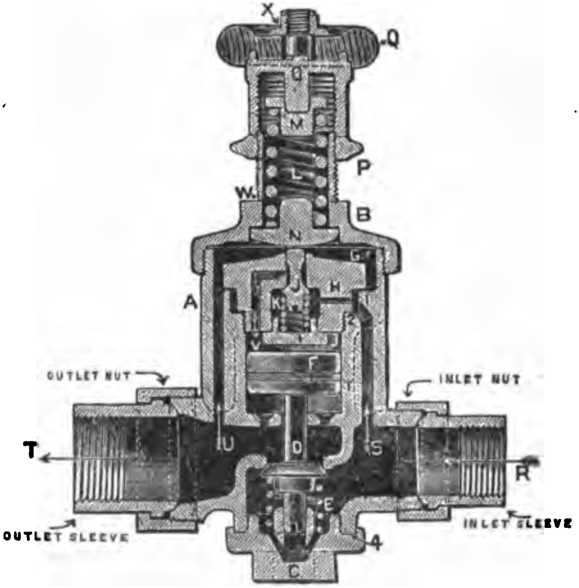


Fig. No. 54

The Leslie Pressure Regulator is operated by the initial or boiler pressure, and is controlled by the reduced or delivery pressure.

Steam enters the Regulator through Inlet "R" and passes up Port "S" and into Controlling Valve Chamber "H." In this way, the boiler or initial pressure is always under Main Valve "D" and under Controlling Valve "J." When properly installed, the

Leslie Pressure Regulator will, automatically, protect itself from injury by dirt or condensation.

To adjust Regulator, Lock Nut "P" being released, screw down Adjusting Cap "O," on Adjusting Spring "L"; this will press Diaphragm "G" down on Controlling Valve "J," opening Controlling Valve admitting the boiler or initial pressure through Port "V" on to top of Piston "F," which opens Main Valve "D," and allows inlet pressure to pass through Main Valve into Outlet "T"; the reduced pressure is admitted under Diaphragm "G" through Port "U."

When outlet pressure tends to rise above the pressure adjusting Spring is set at, it will raise Diaphragm off Controlling Valve, and boiler pressure under Controlling Valve will close it, and cut off inlet pressure to Piston; initial pressure under Main Valve will then close it.

As soon as the outlet pressure falls below the pressure the Regulator is set at, it reduces the pressure under the Diaphragm and the Adjusting Spring acts on the Diaphragm and opens the Controlling Valve again, until the pressure on the outlet becomes equal to the pressure the Regulator is adjusted to and automatically holds, the reduced pressure at which the Regulator is set.

The reduced pressure can be adjusted, to desired pressure, "within the range of the Regulator," by screwing or unscrewing the Adjusting Cap.

THE CHAMBERS THROTTLE VALVE

Operation

The Throttle valve is operated by means of a rod

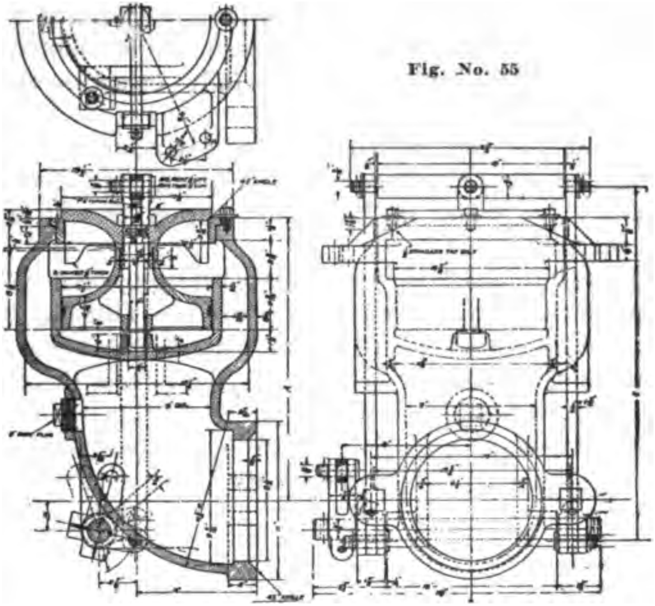


Fig. No. 55

connected to a crank arm located inside of the boiler. As the Throttle lever is moved from closed position, the crank arm moves backward, and, in so doing, actuates the inside lifting arms, with a corresponding movement upward. This, in turn, raises the side bars, which connect with the top cross bar, and to which is attached the Balancing-Drifting Valve. This valve is first raised ⅛", before Main Valve begins to open, and by means of the valve stem, which raises simultaneously, the upper face of the balancing piston, is brought in contact with the provided shoulder on the main valve. The Balancing-Drifting Valve having an unbalanced area of only 2¼ square inches, a very slight pull on the Throttle lever is required to open it. As this action takes place, steam is admitted under the Balancing piston and fully balances the main valve.

Continuing the movement, the balancing piston which has already moved up to a contact, engages the Main Valve, which in turn is lifted from its seat on the balancing ring.

In closing, the Main Valve seats before the Balancing-Drifting Valve. The steam used in Drifting is that which leaves the Balancing Chamber through a small hole in the wall of the balancing piston, thence to the superheater and cylinders.

This device is manufactured by the Chambers Valve Company, of New York City.

LOCOMOTIVE FRONT END APPLIANCES

Locomotives are required to make large quantities of steam to do the work for which they were designed; in order to burn the fuel in the firebox large volumes of air must be drawn through the fuel bed to supply the oxygen necessary to sustain the rapid combustion. The steam exhausting from the cylinders after having done its work against the pistons is used to create the necessary draft and right here we have the two most important and opposing factors, i. e., the steam leaving the cylinders must pass through a nozzle smaller than the exhaust pipe, or base as it is often called. This creates a back pressure on the pistons retarding the effective work done by the engine, but at the same time the sharpness of the exhaust must be maintained sufficient to create the proper draft in the smoke box.

Between these opposing forces some medium must be found that will give the minimum back pressure and maximum draft consistent with that back pressure.

The result sought by the front end designer are—first, sufficient draft to produce proper combustion and assure free steaming of the locomotive under road conditions; second, the minimum back pressure in the cylinders, and third, the elimination of fire or spark throwing.

The draft is produced by the exhaust nozzle petticoat pipe and stack. It is a well-known fact that the velocity and length of steam flowing from the nozzle is determined by the size of the nozzle and the pressure behind it, that is, the higher the pressure the greater length and velocity the steam will have.

The gas friction within the front-end itself must be reduced to a minimum by providing a well-designed stack, ample netting areas, unrestricted gas passages and by eliminating, so far as possible, abrupt changes in direction of gas flow. The mechanical strength of the design should, also, be considered, in order to guard against high temperature, abrasion and violent motion. The ordinary type of front-end consumes much power in doing its work. In a paper before the International Railway Fuel Association at the 1912 convention, Mr. H. B. McFarland of the Atchison, Topeka & Santa Fe Railway showed some startling figures on back-pressure horse-power found during a very comprehensive series of tests covering this subject. An example of this, a 25x28 inch Pacific, with 73 inch wheels and 200 pounds of steam indicated at 50 miles per hour, 350 back-pressure horse power, while a 24x32 inch Consolidated engine with 57 inch wheels and 180 pounds of steam gave, at 25 miles per hour, 260 back-pressure horse-power. Other engines ran to higher figures than these, one large Mallet indicating 1,025 back-pressure horse-power at 25 miles per hour. These all go to show that there is a very serious loss of power by the use of the ordinary front-end.

Figure 57 shows the standard front end arrangement recommended by the Committee on Locomotive Front Ends of the American Railway Master Mechanics' Association in 1906. It consists of the deflector plate, the deck plate, and the diaphragm plate.

The diaphragm plate is in some cases made to swing on hinges having an adjustable plate that can be moved up and down to increase or decrease the space between the plate and bottom of the smokebox.

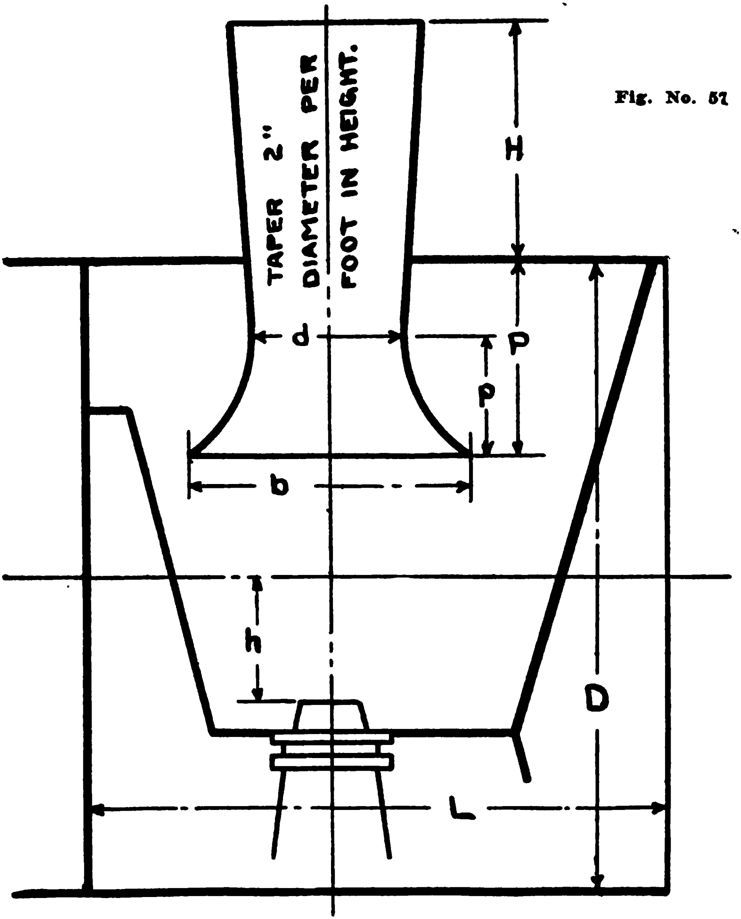


Fig. No. 51

The tip or exhaust nozzle is bolted to the exhaust base or pipe as shown. The stack projects through the first ring or smokebox, having a large flare at its base. (In good front end design this flare is made as large as possible.) The height of the stack should measure from nine to ten inches from the nozzle to give the best results. This will be considered further on.

The deflector plate should be at least three inches from the tube sheet at the top and taper down, as shown.

The netting is attached to the deck plate by means of an angle iron and by same method attached to the smoke arch. The opening of the netting should be at least 72 square inches per square foot, i. e., for each square foot of netting there should be 72 inches of opening.

A properly designed stack should be about one-fourth the diameter of the smokebox when the stack is measured from its smallest point, and taper about two inches in width per one foot in height.

The stack is also influenced by the distance the nozzle is placed below the centre line of the boiler; for example, in the above, one-sixteenth inch would be added to the stack diameter for each inch the nozzle is located below the centre line of the boiler, at h; this is necessary because the greater the distance between the nozzle and stack, the greater the steam jet will expand.

The flare or lip of the stack base d should have a length of about 25 per cent. of the diameter of the boiler ring or smokebox; i. e., the boiler ring or smokebox bottom of the flare should measure 25 per cent. of the diameter.

The inside portion of the stack should measure about 30 per cent. of the diameter of the smokebox. The tapered stack seems to be the more efficient type to use, although some railroads use the straight type.

THE DIAPHRAGM AND DRAFT PLATE

Air or gas currents do not always travel along straight lines but usually move in curves and along the line of least resistance; consequently, without some means of controlling the path of the gases there will be an uneven distribution of the draft over the grate area, and some of the flues would be doing more work than others. The draft plate and diaphragm are therefore put in to control the flow of gases through the flues and to distribute the draft over the grate surface as desired.

The draft plate has, however, another function, namely, to give direction to the gases in their passage from the flues to the stack, and in doing this, to aid in keeping the front end clear of cinders.

We can thus see that in so far as actually creating draft is concerned the draft plate is not a compelling factor, it simply serves to distribute the draft and to assist in keeping the front end clean. However, while the draft plate does not create draft, it is frequently so adjusted as to obstruct it, and in this way becomes a hindrance to the free steaming of a locomotive instead of a help.

The draft or diaphragm plate should always be set so that the opening between the plate and smoke arch is equal to 68 per cent. of the total flue area. If the front end should show a tendency to fill up with cinders when the plate is raised, change the angle of the plate by drawing the bottom further back so it will stand nearly vertical. Furthermore, if the draft plate is too close to the front flue sheet the flow of the gases is so restricted as to cause the locomotive to be what is termed "hot at the door"; consequently it follows that carrying the draft plate as high as possible not only decreases the work of the fireman but also makes his work more comfortable. As it has been shown the draft plate has but two functions.

(Fuel Conservation Section, U. S. R. R. Administration.)

The proper angle of the diaphragm is very important, and from several years' experience I believe the greater angle the better, because the gases will not change their course so abruptly and as a consequence the resistance to their flow is held at a minimum. The front end, like any conveyor of air or fluids, should be as free as possible from sharp changes in direction to the flow in order to secure efficient discharge of the gases.

There are some schemes that can be worked out to overcome the necessity of changing the diaphragm and to maintain the maximum area under the plate. For example, should front end fill with cinders, raise the plate about one inch and place two wings on the sides projecting down three inches below the plate, having a width about four inches, making up perfectly tight so there will be absolutely no vibration when the engine is working. The plates or wings will take up nearly all the area gained between the diaphragm and bottom of the smokebox by raising the plate, in fact, some area may be gained and the net result is little change if any in the gas current passing through the front end. This is the result of actual trials and in every case are workable, provided the diaphragm and wings are made absolutely tight.

In general, when wings are used the area under the plate should be held to at least 68 per cent. of the total flue area.

The theory of the draught produced in a locomotive is due to the entrainment of air currents induced by the stream of steam passing from the exhaust nozzle, while some engineers claim it is due to the exhaust steam completely filling the stack and giving the stack the same action as that of a piston in a pump.

Others claim the entrainment of air currents to be the correct one, because whenever the exhaust steam passing through comes in contact with the sides of the stack two things take place, i. e., the steam rubs against one side or the other, thus greatly reducing its velocity. While this is taking place the flow of gases in the front end is considerably reduced because of the diminished velocity. It must be also remembered that the area of the stack is often 250 square inches less than the space under the diaphragm and but ⅓ the area of the ashpan openings, while the space under the diaphragm and the ashpan openings have nothing but air currents passing through them, while the stack has both the gases and the exhaust steam passing through it.

W. H. Coddington reports some very interesting tests in the Railway Mechanical Engineer, June, July and August, 1918, showing the draft produced by the use of a Waffel iron nozzle. In his conclusions he reports the best draft conditions were found when the steam struck the stack at a point 70 per cent. from the top, using the total length in this measurement, for example—the distance from the top of the stack to a point 70 per cent. downward including the stack extension inside the smokebox. The nozzle used was constructed on a 14 inch diameter circle.

The best results were obtained with a 24 inch stack and 26½ inch inside extension.

A member of the Pennsylvania test department reported before the American Railway Master Mechanics' Association in 1915 the following performance of an Atlantic type engine having 23½x26 inch cylinders with a 6¼ inch circular nozzle, showed an evaporation of 36,928 pounds of water per hour.

The circular nozzle with four projections on the same engine gave an evaporation of 44,628 pounds of water per hour, both nozzles having the same area. Also another test using the rectanguar nozzle, 4¾x6½ inches, showed an evaporation of 38,800 pounds per hour with a draft of 12.9 inches in water.

The report mentioned on page 224 of the Master Mechanics' proceedings the reason for changing to the rectangular nozzle during another test was to bring about a more complete filling of the stack and by so doing an evaporation of 2,500 pounds of water per hour was gained over the circular nozzle of the same area.

TYPES OF EXHAUST NOZZLES OR TIPS.

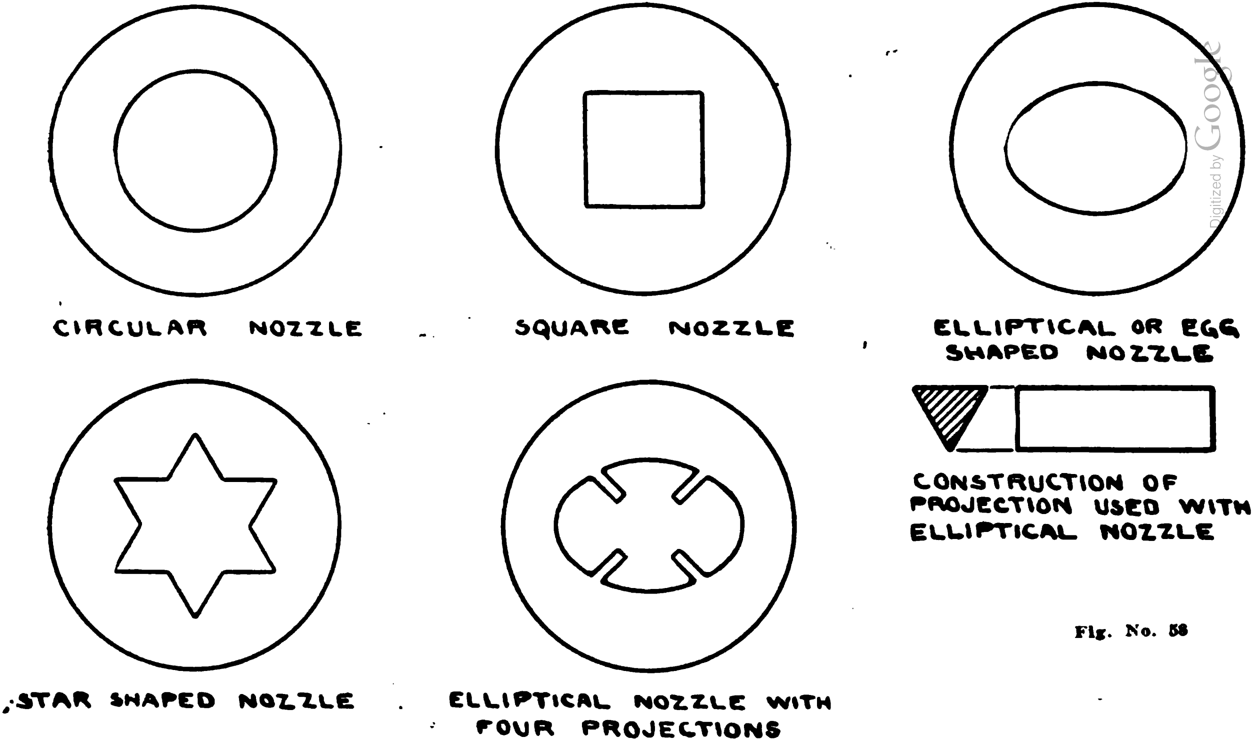

CIRCULAR NOZZLE
SQUARE NOZZLE
ELLIPTICAL OR EGG SHAPED NOZZLE
CONSTRUCTION OF PROJECTION USED WITH ELLIPTICAL NOZZLE
STAR SHAPED NOZZLE
ELLIPTICAL NOZZLE WITH FOUR PROJECTIONS

Fig. No. 58

The conclusions reached so far in front end design and theory of the steam action shows there is much yet to be done before all authorities will be in concurrence as to just what the proper arrangement and proportions are.

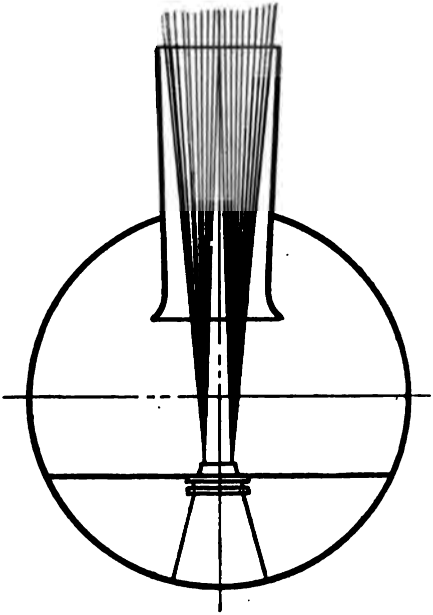


Fig. No. 50

Mr. McBain, in the Railway Mechanical Engineer in 1917, shows there is more draft produced by the steam passing through the stack without filling while the foregoing tests show the contrary to be true.

Many locomotive engineers claim that stacks of locomotives are too large because the exhaust steam does not fill the stack properly. While the exhaust may not fill the stack, the difficulty generally is not here; this is due to the improper alignment of the exhaust and nozzle with the stack.

On the other hand, the stack and nozzle may line up properly and still the stack will not be filled. This, no doubt, is due to the improper height of the exhaust pipe or base; i. e., if the exhaust pipe is too high, the steam will not have the proper space to travel through to allow it to expand to a diameter sufficient to fill the stack.

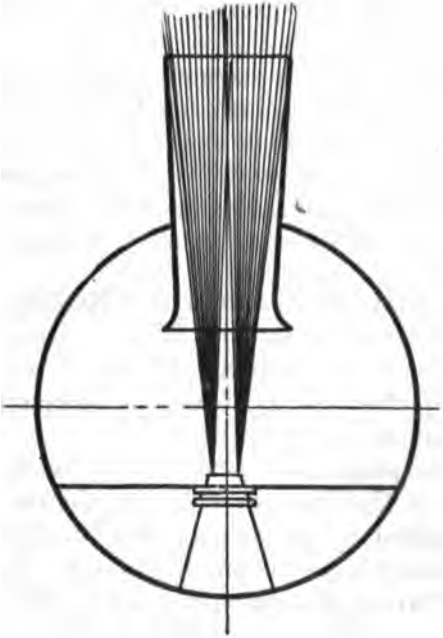


Fig. No. 60

The size of the stack should not be reduced below its recommended dimensions given heretofore, because this would reduce the relative opening between the stack and that under the diaphragm, or baffle plate. It naturally follows that a reduction in the size of the stack will be necessary to increase the stack velocity of the steam and hence, a more restricted nozzle and greater friction of the escaping steam and gases.

Fig. 59 shows the exhaust passing through the stack without filling; the draft therefore will be produced by the entraining of the gas currents.

Fig. 60 shows the jet filling the stack about 30 per cent. of length, giving the steam the same effect as a piston in a pump forcing the air out of the front end.

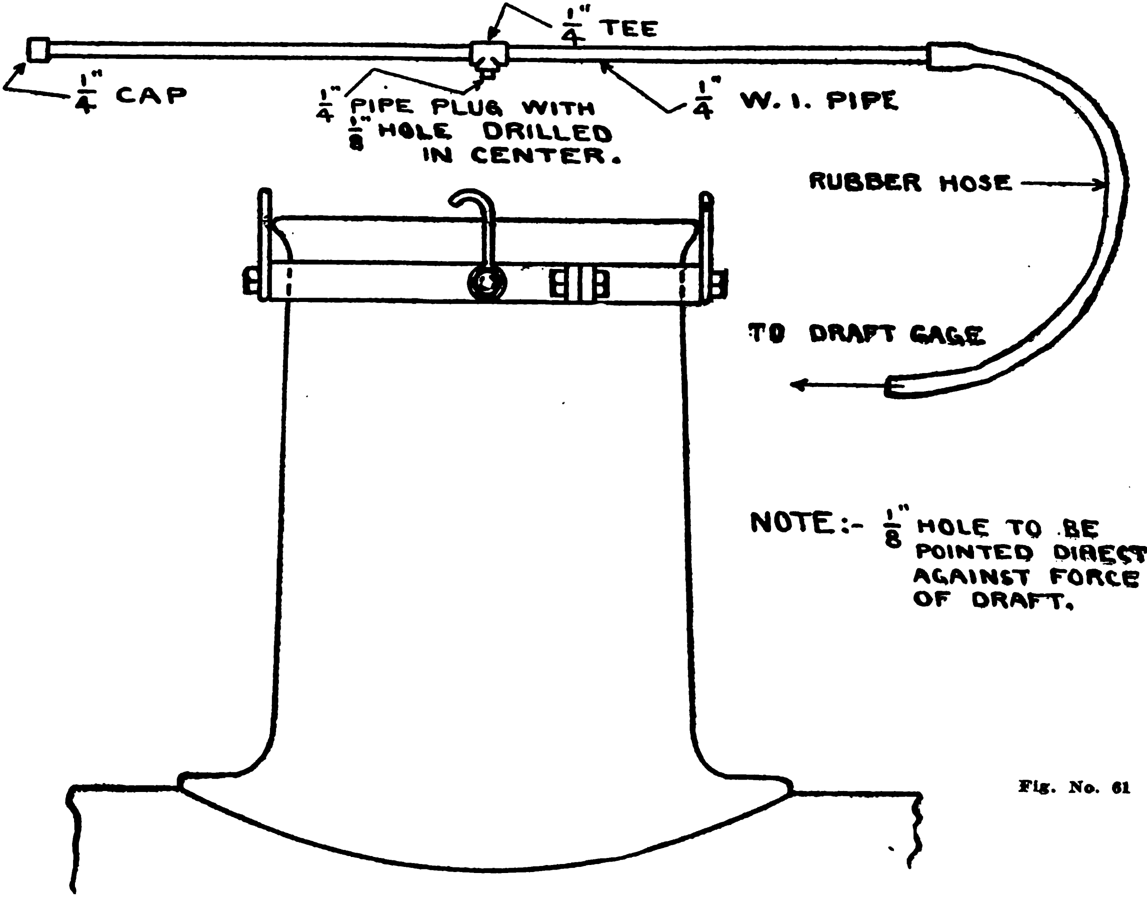
THE RECTANGULAR NOZZLE

The writer made several tests on locomotives of the consolidation type having cylinders of 20x30 exhaust nozzle circular type, 4⅞ inches in diameter, giving an area in square inches of 18.6.

For the purpose of accurately detecting the draft pressure a U-shaped draft gauge shown in Fig. 65 was attached to the side of the smokebox having pipes connected to the end of the tube shown in the Fig. 65, having two pipes, one entered above the netting and the other below with suitable valves for cutting in or out each section.

The quadrant was carefully marked and the throttle opening and steam pressures were the same in each trial. The tonnage hauled was about the same in each case; the conditions were about the same.

The test with circular nozzle showed a total draft


$\frac{1}{4}$" TEE
$\frac{1}{4}$" CAP
$\frac{1}{4}$" PIPE PLUG WITH $\frac{1}{8}$" HOLE DRILLED IN CENTER.
$\frac{1}{4}$" W. I. PIPE
RUBBER HOSE
TO DRAFT GAGE

NOTE:- $\frac{1}{8}$" HOLE TO BE POINTED DIRECTLY AGAINST FORCE OF DRAFT.

Fig. No. 61

pressure of 9 inches in water, average in the front end with the engine working about ⅔ stroke or cutting off at 20 inches, while under the same conditions a rectangular nozzle of the same area in square inches gave a draught pressure of 12 inches in water.

These results tend to show clearly two improvements; the exhaust or jet shot through the stack with less friction gave a greater velocity and a greater space for the entrained gas currents to pass out.

The pressure of the jet was measured by a device shown in Fig. 61, having the U tubes as used in the draft gauge but filled with mercury instead of water, having much greater weight. This device was hooked into the stack fastening shown and drawn across the stack from one side to the other, registering in so many inches for each position. This device measured accurately just what was going on in the stack and the stack pressure in inches shown on the rule multiplied by 2.2 gave the stack pressure at any point in pounds. Connection F, Fig. 65, was used for the registering of stack pressure.

The test was made on a slow freight train, but speeds of 20 to 25 miles per hour were attained with gratifying results.

CHANGING NOZZLES TO DECREASE FUEL CONSUMPTION

The exhaust nozzle may be enlarged to decrease fuel consumption when the engine steams freely, but there is a limit to this. The writer making experiments along this line was surprised to find no perceptible decrease in fuel consumption when an exhaust nozzle of 5⅛ was substituted for one of 5 inches on an engine having cylinders 20x30 inches.

Further investigation disclosed an increase of front end temperature when the exhaust nozzle was increased. The cause was no doubt due to the slowing down of the gases passing through the tubes and flues.

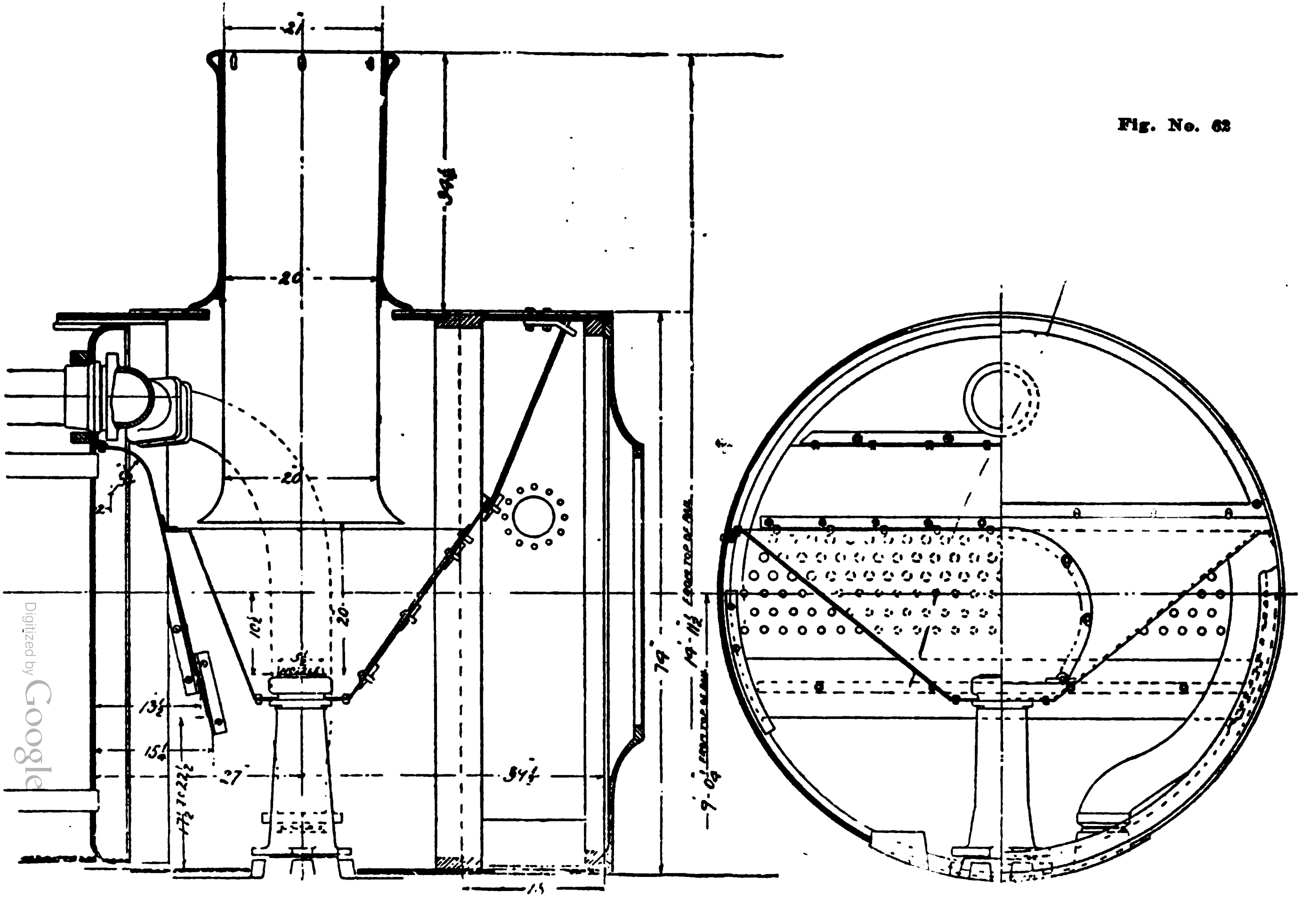
The action of gases in the above may be explained in the following manner: For example, when the hot gases passing through the flues come in contact with the metal they are cooled and form layers of cooled gas against the metal like a large admission of air through the firebox door on an engine having a brick arch; these layers are poor conductors of heat and, therefore, the gases pass to the front end at a higher temperature, not giving up as much heat as they would had the velocity not been decreased.

Whenever experiments of this kind are made it is well to use a front end thermometer or pyrometer attached at some point behind the netting so the temperature of the escaping gases can be accurately determined for comparison.

Fig. No. 62 shows the construction of the Turner Front End as used by the Fitchburg Railroad some years ago. This type shows many good features, principally the large netting area and location of the exhaust pipe or base at a point 10½ inches below the center line of the boiler. The distance between the exhaust nozzle and base of the stack is 20 inches, giving an advantageous gas entrainment space for the steam jet to act.

It will be noticed there is no deck-plate or table and

Fig. No. 62


21"
34½
20"
20"
10½
20
5½
13½
15¼
17½ to 22½
27"
54½
1.5
79"
14'-11½ Edge top of rail
9'-0¼ Edge top of rail

no diaphragm plate used and a large generous opening under the baffle-plate.

THE EXTENDED FRONT END

Several years ago the extended front end was used on railroads. The theory of the extended front end was like the air chamber on a steam boiler feed pump, that is, the large front end would promote a more even and uniform draft. Later, this theory broke down under tests. It was shown that the extended front end did not produce as high a vacuum as one having smaller dimensions. It proved the limitation of front end size and showed there was a greater draft produced by the smaller over the extended smokebox.

The writer recalls some difficulty had by a large railroad in making several engines of the Mallet type steam. The introduction of cement mixed with sand was used near the boiler front end plate to cut down the front end volume; favorable results were reported from this experiment.

THE SIZE OF THE EXHAUST NOZZLE

A fairly good rule for determining about what the engine should have had a circular nozzle may be stated for engines having small fireboxes on top of the frames but not extending out over the driving or trailer wheels: divide the cylinder diameter by 4.1 and for engines having wide fireboxes extending out over the locomotive frames, divide the cylinder diameter by 3.9. This will give something fairly accurate to work from. Working out the problem, take an 18-inch cylinder engine. We have $18 \div 4.1 = 4\frac{3}{8}$, nearly ——. Then taking a 22-inch cylinder Pacific type engine we have 22 ÷ 3.9 — 5⅝ about. This rule, of course, is to be verified by actual trial on the road. However, when engines will not steam with tips used from the above example, a careful inspection of the front end should be made to ascertain whether or not there are any steam pipe or air leaks in the front end or the diaphragm plate too low.

LINING THE NOZZLE

The exhaust nozzle should line up with the stack absolutely central and should never be set with a plumb line, because the engine may not stand level on the springs or the rails may be higher on one side than the other. This would cause a line to fall to one side of the nozzle and an error would result.

The best way to line the nozzle with the stack is by use of a rod or bar, setting it central at both top and bottom of the stack, having the lower end long enough to allow the nozzle to be set central with the bar or rod falling through the centre of the tip.

The rod could be made with a tee-shaped end and by a clamp on the top of the stack with a sliding clamp and centering studs attached so that it can be centered at the bottom as well as the top. This method will correct any error that might result from the engine not standing level.

THE PETTICOAT PIPE

In the modern locomotive the only function of the petticoat pipe is to increase the stack length; therefore it should fit tight into the base of the stack and be made nonadjustable, that is, it should simply be a stack extension.

REDUCING THE NOZZLE TO MAKE A LOCOMOTIVE STEAM

This is a standard remedy with the average roundhouse man, and is frequently used to cure all ills the locomotive is heir to. Reducing the nozzle should be the last resort, as it not only reduces the efficiency of the locomotive, but materially increases the coal and water consumption as well as the work of the engineman.

Changes in the physical characteristics of the fuel or climatic conditions make it necessary at times to increase the draft, but instead of bushing the nozzle better results can be obtained by applying a rectangular of dumb-bell shaped tip of the same area, or better yet, bore the tip out ¼ inch larger, then apply a ⅜-inch round bridge, spot welded at each end to make it stay in place.

When changing from the circular nozzle to any other type the area of the circular should equal that of the new form.

DRAFT INEFFIENCY

Under this head would come anything that in any manner interfered with or reduced the draft. The worst offenders in this direction is the front-end air leak, especially in superheated steam locomotives with steam pipes extending through the smoke arch. As a rule, in order to permit of their easy application and removal, the hole through the arch is cut large enough to accommodate the flange of the pipe. This opening is then partially closed by means of a split collar or bushing. In practically all of the locomotives built prior to 1918 this collar or bushing still left an opening around each pipe equal to a round hole 5¾ inches in diameter; consequently, when the exhaust creates a partial vacuum in the front end, some air moving along the line of least resistance will be drawn in through these openings instead of through the fuel bed, thereby decreasing the draft by that amount, making it necessary to reduce the nozzle in order to maintain the necessary vacuum. Tests have proven that sealing these openings permitted an increase of from ¼ inch to ⅜ inch in the diameter of the nozzle, resulting in a decrease of from 14 to 21 per cent. in fuel with a corresponding increase in engine efficiency, at the same time very materially improving the locomotive's steaming qualities.

Another draft inefficiency found in superheated steam locomotives is the superheater damper. This should always be set at an angle of 60 degrees when open, the top of the damper leaning back; if set vertical it obstructs the draft through the bottom flues.

Among other draft inefficiencies can be mentioned steam leaks in front end either at steam pipe or nozzle joints or at the connections between the superheater units and header. Any steam thus escaping into the front end tends to fill the vacuum being created by the exhaust jet and so reduces the draft. While the unit joints may leak quite a little without affecting the steaming of the locomotive materially, these leaks nevertheless can waste considerable steam, and in this way waste fuel.

(Fuel Conservation Section, U. S. Railroad Administration.)

DETECTING AIR LEAKS

A very convenient method for finding front end air leaks is as follows: Have the fire burning brightly; place two or three shovels full of coal on the fire, spreading it thinly and quickly cover the stack, close the firebox tightly and watch all front end joints where air is likely to leak. If there are any spaces the smoke will issue according to the size of the opening. Take a piece of white chalk and mark all the places so that repairs can be made without repeating the test.

Front end leaks should be carefully and promptly remedied. Often smoke arch fronts will leak air around the bolt holes and flange and often around the base of the stack or hand-holes. Whenever the lower flange bolts are loose the front end will become red hot. This is due to the oxygen of the air entering and igniting the hot cinders sufficiently to sustain a fire in the smokebox.

DETECTING FRONT END STEAM LEAKS

Leaky steam and exhaust pipes may be tested by steam in the following manner:

Open the front end; set the brakes, give the engine steam; if leaks are present a hissing sound will be heard or, in fact, the steam may be seen issuing from the joints. This test can also be made without opening the front-end door in the following manner:

Shut off the air pump, give the engine steam; have the firebox door open a little and listen. If the leakage is quite large it will be heard. It is often difficult to tell whether the steam pipes leak or a leaky main valve is present.

The exhaust base and tip can be tested for leakage at the flange by setting the engine on the quarter, applying the brake, giving the engine a little steam and having the reverse lever worked from front to back corner; then with the front end open the observer can see the steam shoot out between the flanges if leakage exists.

The best method for testing leaky steam pipes, exhaust bases, and nozzles is by use of the water pressure method. There are two methods of testing in this manner. The best is to remove the tip and use a blank flange over the connection to the base, where the tip is connected, inserting a piece of rubber packing to make it air tight; then remove a cylinder cock, or port plug; attach a hose and by use of a boiler tested, if convenient, run up a hot water pressure of 100 pounds and then examine all steam pipes and the exhaust base for leakage. It will be necessary to block the wheels and set the tender brake to prevent the engine moving under the pressure of water exerting its force in the cylinders.

Other tests can be made by filling the boiler full of water and applying 100 pounds pressure with the throttle valve open; the results will be about the same. This test requires more time and water.

CHOKED NETTING AND FILLING THE FRONT END

Plugging netting or front ends filling is directly traceable to loose diaphragm plates or in some instances to the manner in which the netting is installed.

When the perforated steel plate is used, it will often be found larger on one side than on the other. The side where the punch enters is generally slightly larger than the end where it passed through the sheet and will often be slightly burred. In most cases the burred or smaller side should be set out toward the gases so the sparks will not become wedged and stop the netting up.

THE EXHAUST PIPE OR BASE

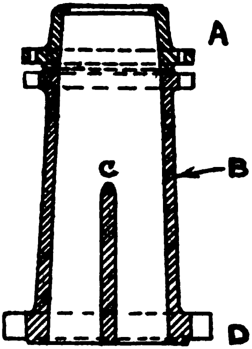


Fig. No. 63

One of the obstructors of an even exhaust jet is the bridge in the exhaust base, see Fig. No. 63. Where the space is small between the bridge and walls of the exhaust base or exhaust pipe, it will cause the jet to rub against the side of the stack, while the front and rear will not be properly filled.

The rectangular type of nozzle in Fig. 58 when used will often overcome this difficulty.

Figure 63 shows the exhaust pipe or base commonly used on locomotives having single exhaust nozzles. The bridge "C" in the middle of the figure is to prevent the steam when exhausted from the cylinders passing from one side to the other.

It has been shown from tests that the bridge often prevents the exhaust steam from filling the stack or making an even jet all around while passing through.

A very good plan to help this situation has been worked out as follows: By use of an oxygen-acetylene torch it is possible to cut out the exhaust base for a length of five inches and a width of three or four; cutting down along a line on the side parallel with the bridge, then applying a piece of boiler plate made dished with this part set out so when placed on the base the chamber between it and the bridge will be enlarged. The plate can be put on by use of studs and a gasket to make a steam tight joint or by use of modern welding devices.

Figure No. 64 shows the construction of an exhaust base or pipe made to eliminate some of the trouble experienced with the base explained in Figure No. 63. Some engineers claim the bridge should not project up so high in the exhaust base as it will be found in some of the older type engines, claiming that the bridge does not help to keep the exhaust away from the opposite cylinder as much as it was generally un-

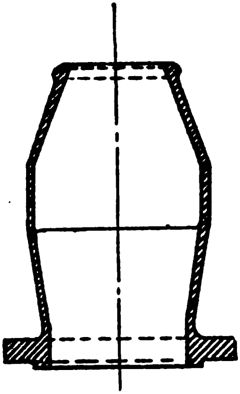


Fig No. 64A

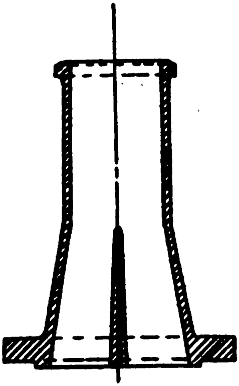


Fig. No. 64B

derstood to do and the loop often found on indicator cards shows that it is due to a restricted exhaust port opening instead of the exhaust from one cylinder passing over against the piston on the opposite side.

For example, when starting a heavy train should the valves be improperly set there may be a restricted exhaust port opening under the valve occasioned by working at long cut-off and when the indicator is applied it is often mistaken as exhaust steam passing from one cylinder to the other, whereas the real trouble is with the valve setting.

The high base or exhaust pipe was used years ago very extensively; the prevalent idea was that it prevented high back pressure, but late years there seems to be a tendency to shorten it and give the exhaust steam a longer entraining space between the nozzle and petticoat pipe.

Whenever changes in width of the exhaust base are made every opportunity should be taken advantage of to raise the diaphragm plate; for example, when a larger base is substituted the draft area under the diaphragm will be somewhat reduced; this being brought about by the base having greater width and therefore by raising the plate, this space will be compensated for, having in mind that the exhaust base performs the same function as the diaphragm plate so far as assisting in cleaning the front end, because cinders will be thrown against it and broken in the same manner as done when they are thrown against the diaphragm plate.

THE DRAFT GAUGE

Referring to Fig. 65 we have here an ordinary tube for the purpose of getting the draft pressure in the front end of a locomotive.

The parts of the gauge are A, the back made of a thin piece of hard wood, the glass tube K-L fastened to the wood at the points C and D, the scale marked in equal graduations from zero to 13.

A pipe is attached to the upper left side, may have two branches with suitable valves to cut out each for testing the draft behind and in front of the diaphragm plate.

The operation:

The gauge should be set at some convenient point on the front end, the connections G and F piped into the smokebox, one inside of the netting, the other behind the diaphragm plate. One valve at a time only should be opened. For example, assume F is attached to take the vacuum behind the netting and you get a reading on the scale of 5 inches, and you desire to see

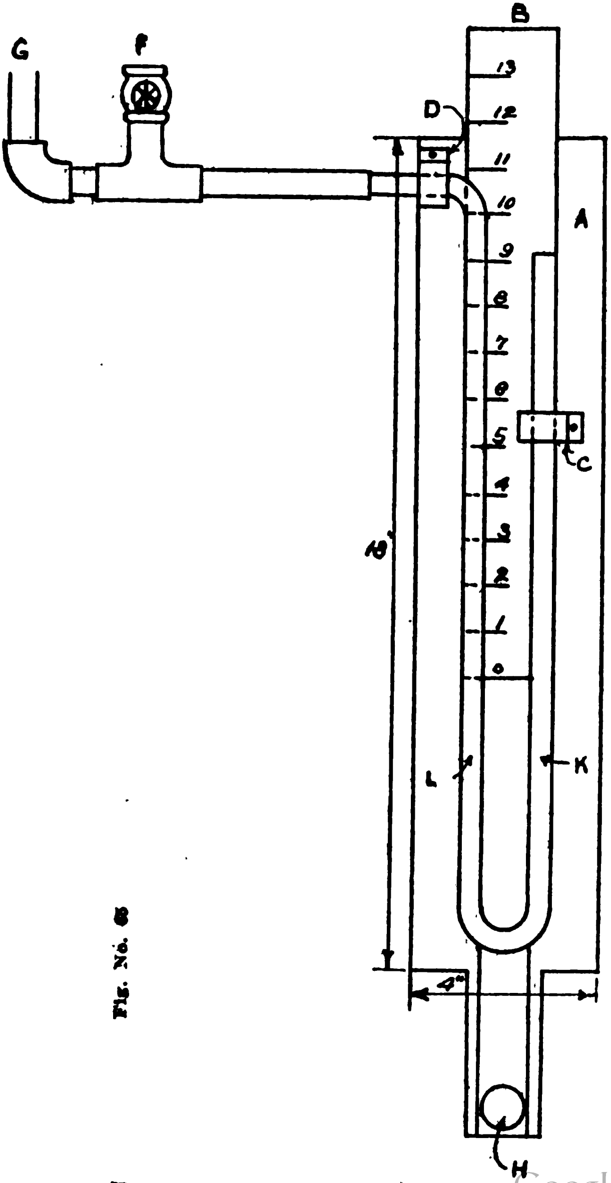


Fig. No. 8

just what the vacuum is behind the diaphragm plate to show what resistance is being offered to the flow of gases. By closing valve F and opening a valve attached to G we will get the vacuum behind the plate. The scale is made adjustable so that it can be moved up and down as the condition of draft changes; the mark zero should always be pulled down to equal the water level in K because this will indicate the difference in pressure. For example—the vacuum formed in L will cause the atmospheric pressure to force the water down in K and up in L so the total displacement must be measured by the distance between the relative water levels in both sides of the gauge.

It is often convenient to make an improvised gauge by using a piece of ⅜ wrought iron or brass pipe bent in the manner as shown in L, using a pipe for one leg of the gauge instead of the glass tube. For example—starting at D, bend the pipe, making all the angles until we get to the lower straight section K, leave a thread near the return bend on K and cut a water glass packing gland threading it so it can be screwed onto the pipe and attach a water glass to this connection, leaving the upper end of the glass open. Reverse the readings of the scale and fasten it to the board at the right side leaving about 3 inches from the top of the water glass to the highest water level at which the scale marked zero should be set. The glass should have a length of at least twelve inches for the water to pass through and of course the leg of the pipe shown as L should be made at least 24 inches long from the water glass gland to the upper left hand bend. The scale graduations should be in half inches because we are to read but one side of the tube, therefore a reading of two graduations would indicate two inches, although the actual distance moved in K would be but one inch.

There will often be a tendency for the water to slop over the free end of the gauge when starting a heavy train or the sudden slipping of the driving wheels; to overcome this, use about a dozen pieces of small lead shot dropped down into the return bend of the gauge; the pressure will then move up and down less quickly and prevent the exhaust from giving the water a momentum as the engine starts. The last described draft tube can be used on fast trains because its reading requires no adjustment of the scale, whereas the first described would require a man to ride out near the front end and therefore is better adapted to be used on slow freight engines. The U tube is the only proper way to test the front end appliances because it is possible to determine just what is going on. For example—if there are steam pipe or superheater units leaking or air leaks, the vacuum will be lower than it should be; if the diaphragm is not high enough a comparison can be made here as explained.

It is a good plan to attach the gauge to a good steamer, get the readings and then check a poor steamer with the gauge to show up their relative performance.

LOCOMOTIVE VALVES AND VALVE GEARS

FOREWORD

There are two types of main valves used today on locomotives, the common "D" slide valve and the piston valve.

The "D" slide valve is so called because it resembles the letter D. It travels back and forth on its seat under the influence of the eccentric; the full distance it so travels is known as the valve travel.

Locomotive valves have steam lap for the purpose of working steam expansively and economizing on fuel and water, lead to help to start the engine and to fill the clearance space with live steam to cushion the reciprocating parts of the engine.

Clearance or negative exhaust lap on fast passenger engines to obtain quick escape of steam from the cylinders after its work is done against the piston.

Steam lap is the distance the valve overlaps the steam ports when the valve is central position measured from the outside edges of the steam ports for a slide valve or outside admission piston valve. With the inside admission piston valve, steam lap is the amount the valve overlaps the steam ports when in central position, measured from the inside edges of the steam ports.

Clearance is the amount the inner edges of the valve fail to cover the steam ports on the inside when the valve stands central.

With an inside admission valve clearance is the amount the valve fails to cover the steam ports on the outside when the valve is in central position.

Lead is the amount the steam port is open when the engine stands on the dead centre; with some types of valve gears lead is constant while others variable as the lever is hooked up, will be explained further on.

Cut off is the point of the stroke when the steam is shut off from entering the cylinders measured as so many inches; for example, eight-inch cut off would be at a point when the piston had traveled eight inches of its stroke; the remainder of the stroke steam works by expansion.

Port Opening. Is the extreme displacement of the valve from mid-position minus the steam lap.

Preadmission. Is the establishing of communication between the steam chest and cylinder.

Admission. Is the establishing of communication between the steam chest and the cylinder and takes place on the steam edge of the valve continuously between the point of preadmission and the point of cut-off.

Release. Is the opening of the steam port by the exhaust edge of the valve.

Closure and Compression. Is the closing of the steam port by the exhaust edge of the valve.

THE STEPHENSON VALVE GEAR

The Stephenson Gear as applied to a locomotive consists of four eccentrics which are keyed to the main axle generally, but for convenience are sometimes placed on the axle ahead. The eccentric cams are enclosed in the eccentric straps; attached to the straps are the eccentric rods which are also connected to the link, the go ahead at the top and the back up on the bottom of the link.

The motion imparted by the eccentric to the link is then given to the link block to which is fastened by a link block pin to the lower rocker-arm or transmission bar depending on the rocker-arm construction. Through the rocker arm the motion is then given to the valve rod stem and valve yoke in which is enclosed the main valve. The travel of the main valve is regulated by the link which is suspended by a link saddle pin, link hanger lifting arm, tumbling shaft, reverse arm reach rod, reverse lever and quadrant. The motion of the link above the link saddle pin is controlled by the go-ahead eccentric. The motion below by the back-up eccentric. By lifting the link saddle pin above the link block pin which is accomplished by placing the lever in back gear the work is put on the back-up eccentric. When the link saddle pin is below the link block pin, the engine is in the forward gear.

The Stephenson Gear is called a floating link motion because the link is movable. When the link block pin is opposite the link saddle pin and the engine on the quarter the valve should stand central. When the engine stands on the dead centre and the lever in the centre, the steam port will be open the amount of lead the engine has.

When the top or extreme end of the link is as near the link block as possible this will allow the engine to work in full gear.

Fig. 66 shows the general outline of the Stephenson gear, the eccentrics indicated by the arrows A and B, the eccentric rod C attached to the strap as shown, the forward end of the rod is made with a jaw for the purpose of attaching them to the link. The distance shown as A is angle of advance the amount the eccentrics are moved beyond the 90 degree position in order to overcome the lap of the valve and give the desired lead.

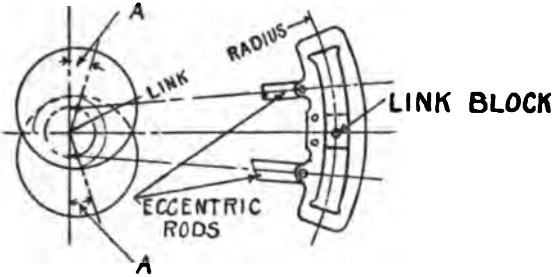


Fig. No. 66

REVERSING THE STEPHENSON GEAR

By moving the reverse lever to full back position the link is raised up, the backing up eccentric will then control the valve movement the reverse to that of the go-ahead or forward motion.

When the link block is set in mid position between the top and bottom of the link the engine is said to be in mid-gear.

SHORTENING THE CUT OFF

To shorten the cut off and work steam expansively, the reverse lever is hooked up. This raises the position of the link relative to the link block and decreases the effect of the eccentric on the valve; this makes all events of the stroke earlier by decreasing the effect of the eccentric throw and increasing the angular advance.

Fig. 67 shows the link used with the Stephenson

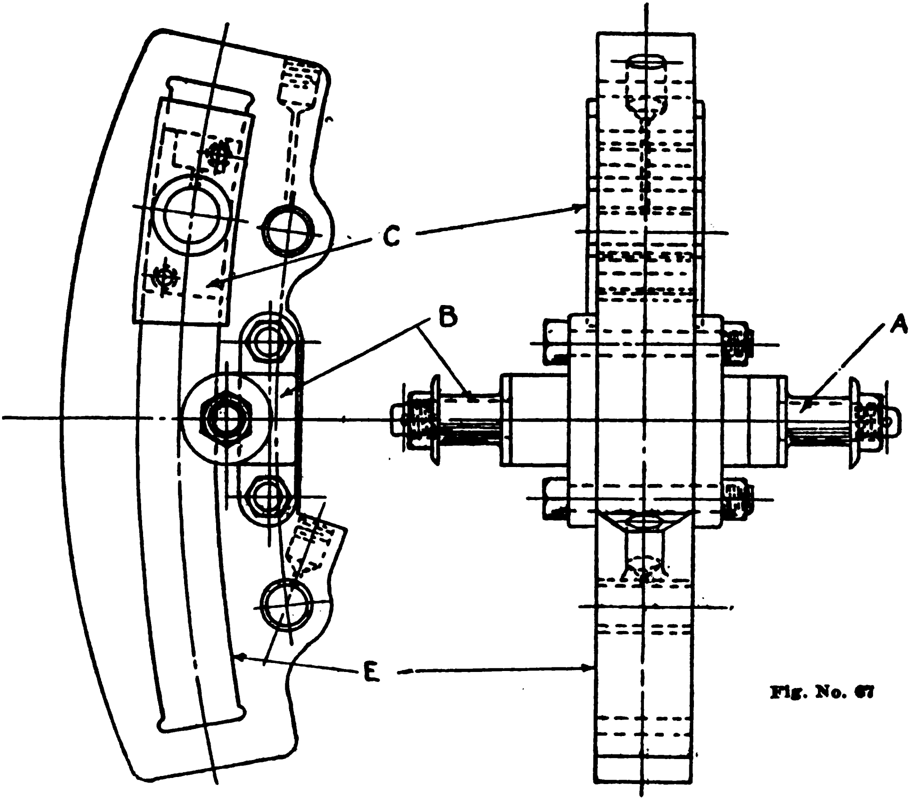


Fig. No. 67

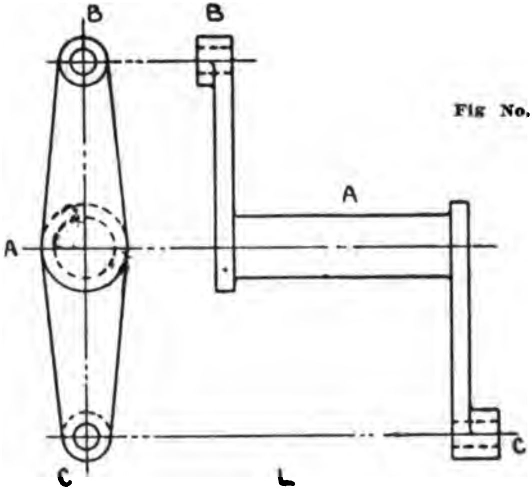
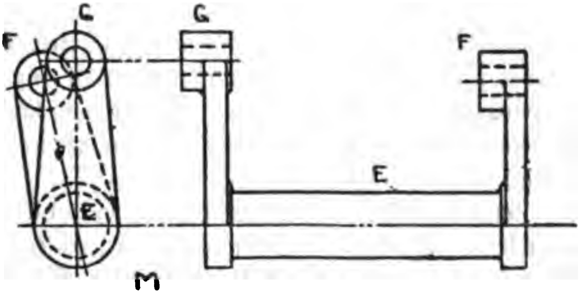


Fig No. 68



gear E. E., the link A, the link block pin B, the link saddle pin or stud, and C, the link block.

It will be noticed that the link saddle pin does not set opposite the radius line passing through the link centre; this is known as the offset and is used to overcome the angularity of the main rod. See Fig. 76. The offset gives the link a lever-like action, lifting and lowering its position. It is necessary to give the link this offset because the link block falls ahead of the proper position relative to the main pin when the crosshead is running ahead and falls back when the crosshead is running back. The act of lifting and lowering the link increases or decreases the influence the eccentric has on the valve, equalizing the cut off on each side of the piston.

The link block pin is attached to the rocker arm, although in some instances is attached to a transmission bar to carry the motion ahead to a rocker arm and valve rod to the main valve. Fig. 68M shows the construction of a direct rocker arm. L an indirect rocker arm.

LEAD OF MAIN VALVES

Most outside valve gears are designed to give constant lead, although there are some types of engines in fast passenger service running with what is known as distorted valve gears explained further on as valuable lead.

Many leading valve gear experts favor variable lead gears such as the Stephenson in so far as its effect on distribution of steam in the cylinders.

The locomotive when running at high speed requires more lead than at slow speeds and it is advantageous to have a fairly large lead opening. Engines having outside valve gears have running lead in the corner or full gear, that is a disadvantage because there will be preadmission in the cylinders when the engine is starting a heavy train.

THE ECCENTRIC

The eccentric is simply a collar placed around the axle, but the centre of the collar is set over so the rotation or turning of the engine gives it an action like that of a crank. This motion is carried on to the main valve as explained before.

Fig. 70 shows the eccentric without being set over. That is, the centre of the eccentric coinciding with the centre of the axle, and Fig. 70 also shows the eccentric after being set over, so that it gives a crank-like action. The circle produced by the eccentric is

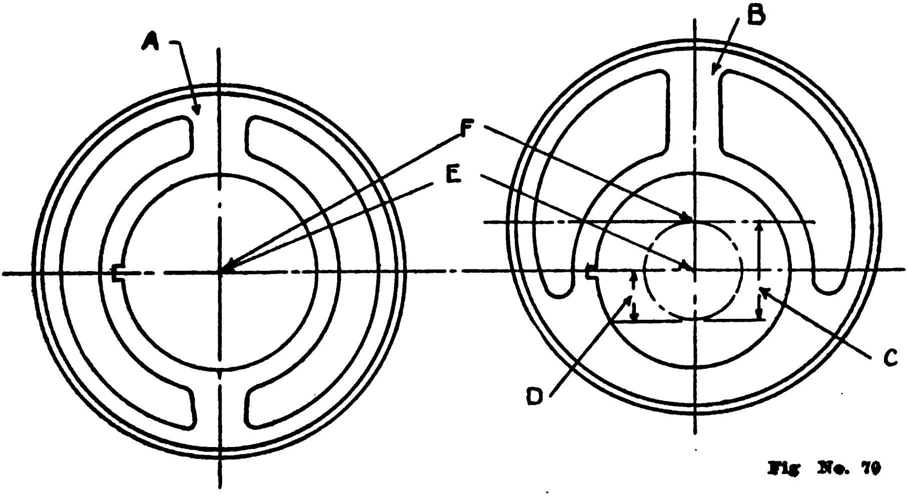


Fig No. 70

equal to twice the distance from the centre of the eccentric to the centre of the hole where it fastens to the axle because it travels that distance each way like an engine having a 30 inch stroke; the main pin is 15 inches from the centre of the axle, but it travels this distance each way.

Eccentrics are set generally 90 degrees ahead or behind the main pin and enough more ahead or behind to overcome the lap of the valve and give the lead desired.

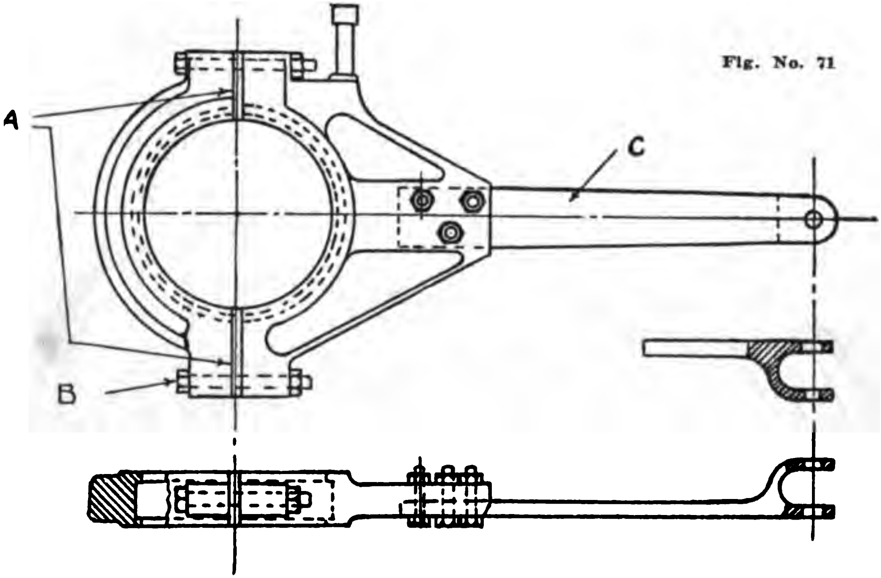


Fig. No. 71

Most railroads locate the eccentric back of the main pin relative to the running direction on all types of the Stephenson gear. In order to have proper lead in cases of this kind, an indirect rocker arm must be used, otherwise the engine would back up under the influence of that eccentric, but however, when the inside admission valve is used the rocker arm must be direct. Why? Because an inside admission valve moves back to admit steam while the outside admission valve moves ahead. For example—assume the piston is at the end of the stroke front centre for example. An outside admission valve must move back whereas an inside admission valve would have to move ahead to admit steam to the cylinder.

Fig. 71 shows the eccentric straps indicated by the arrows A and B, also the eccentric rod C attached to the strap as shown.

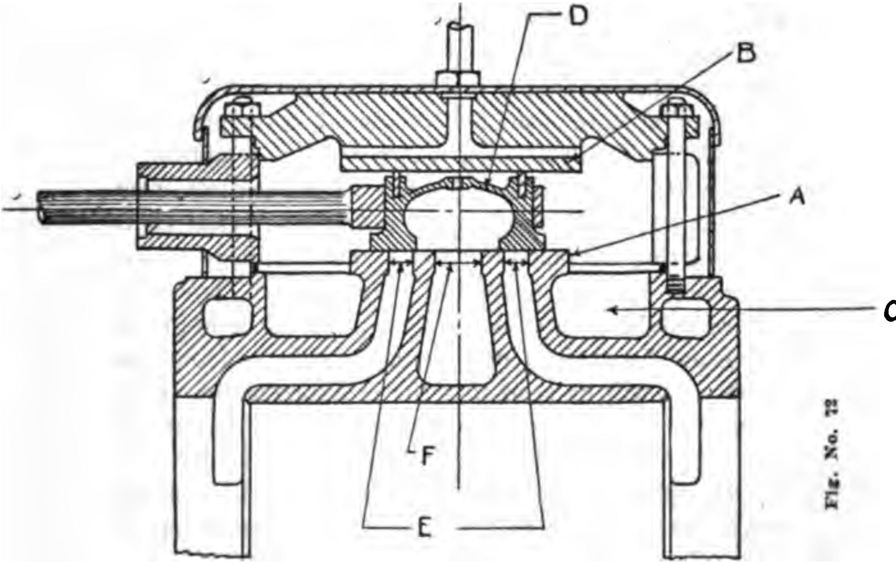


Fig. No. 72

The forward end of the rod is made with a jaw for the purpose of attaching them to the link.

Figure 72 shows the Allen Richardson Balanced Valve.

The steam chest cover and method of attaching need no description since it can be clearly seen from the figure. A shows the valve seat B, the balancing plate; D the slide valve with the packing strips held against the plate B; a small hole will be noticed on top of the valve directly over the exhaust port F.

C is the admission port, one on each side of the valve seat but not indicated on left side.

The steam lap of the valve is shown by the distance the valve overlaps the steam ports E on the outside, the valve setting in mid position in the figure.

There is a slight overlap on the inner edges of the valve as shown; this is inside or exhaust lap.

Referring to the top of the main valve, the provision for balancing will be seen when steam is admitted to the chest; the small strips keep the pressure from getting on top of the valve, making a steam tight joint resting against the plate B under tension of the balancing springs. Should they leak by, however, where would the steam go? Out the small hole in the valve as shown into the exhaust cavity and out the stack. It will be seen that the pressure in the cylinders help to balance the valve after steam is cut off. For example—assume there is steam in the left end of the cylinder; here we find a pressure against the valve seat tending to lift it and hence balancing it somewhat; a section of the valve yoke can be seen surrounding the valve and the stem attached to it and passing through the stuffing box on the left of the figure.

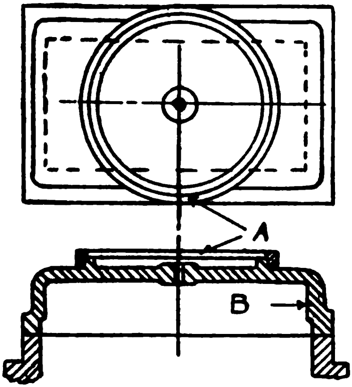


Fig. No. 73

Fig. 73 shows the American balanced slide valve.

It will be noticed that the circular disk is used to keep the pressure from the top of the valve instead of strips as used in the Allen-Richardson valve.

The amount of balance given to the valve is shown by the relative areas of the top of the valve as compared with that enclosed by the circle; this balance runs about 65 per cent. of the area. However, some figure the area of the ports and bridges to determine the proper balance. For example—assume we take one steam port, the exhaust port and the area of both bridges between the steam and exhaust ports; this same is then applied to the top of the valve as its balancing area.

Fig. 74 shows the construction of a piston valve.

Fig. No. 74

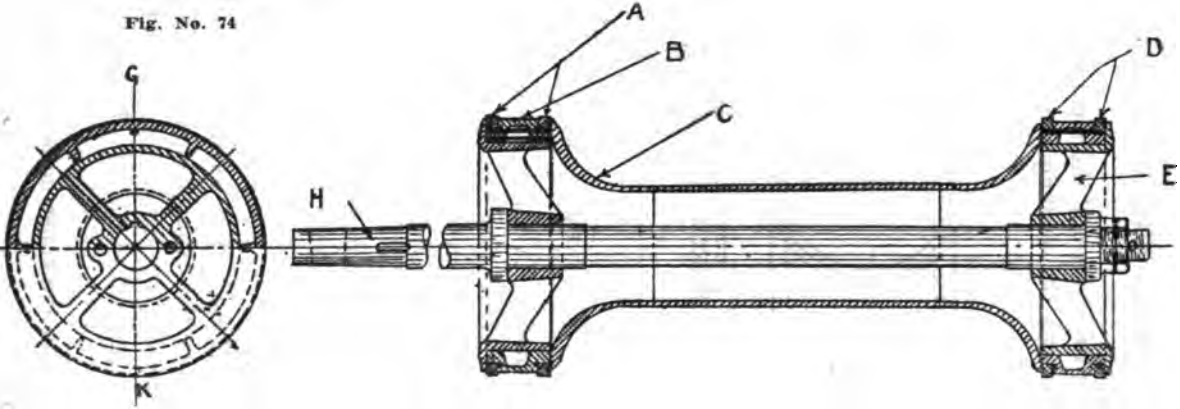


Fig. 74B, showing Streamline Cylinder Port Arrangement for New Engines using Piston Valves.

Streamline Cylinder Ports make application of the well known principles governing the flow of gases—principles recognized as fundamental in the design of steam turbines.

With Streamline Cylinder Ports it is not necessary to make the circumference of a piston valve any greater than the length of a slide valve port.

By properly directing the flow of steam to and from the valve, every square inch of the bushing port becomes effective. This permits the use of a valve only half the size of the older type, and, at the same time, facilitates the flow of steam to and from the cylinder to such an extent that the engine is noticeably smarter and faster.

The advantage of light weight valves is obvious. Fourteen and sixteen inch valves weighing from 225 to 300 pounds produce, at high speeds, stresses in valve stems exceeding 7,000 pounds. This figure is greatly augmented in certain parts of the valve gear. Streamline Cylinder Ports cut the valve weights in half and reduce the stresses in proportion.

It is difficult to conceive how sufficient steam to produce an indicator card can enter a port opening only 5/16 in. to ⅜ in. wide, the admission period being no longer than the "snap shot" of a cheap camera. It is evident that obstructions, cramped passages, and sharp turns exist at the expense of the admission line. Streamline Cylinder Ports by eliminating obstructions give a better admission line and lower the back pressure line.

During the exhaust stroke, the greatly expanded steam must be forced out through this same passage, the port opening being but little wider and the period a little longer. Properly designed ports will relieve pounds of back pressure, which means thousands of pounds added to tractive effort.

DESCRIPTION

Fig. 74B shows the application of these principles to new power, where design of the cylinders is under

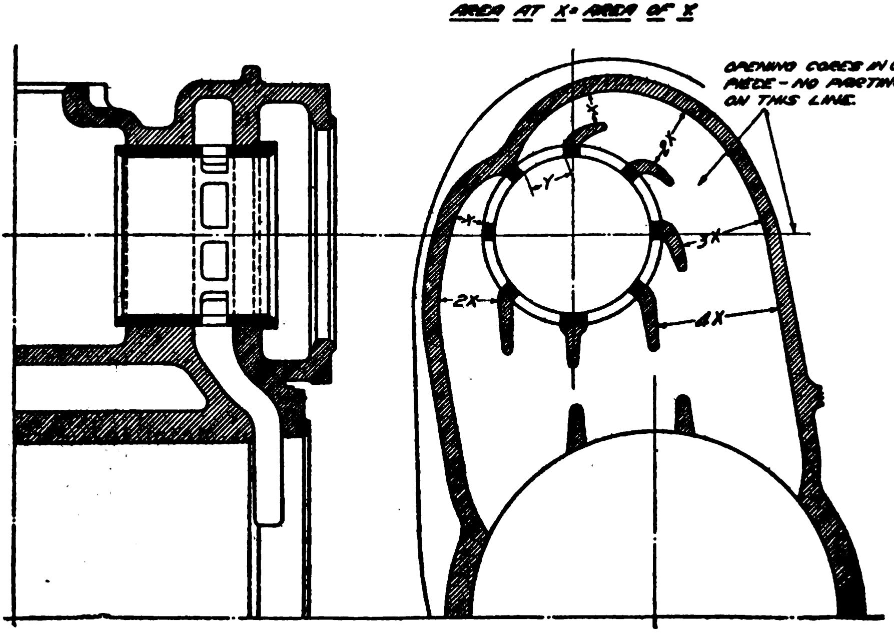


Fig. No. 74B

control. Y equals the area of each bushing port. X equals Y in area. Thus it will be seen that the steam port around the bushing is so arranged that during the admission period as steam issues from the valve, it is divided into a number of streams, depending upon the necessary number of bridges in the bushing. These streams are directed by the ribs so that they do not interfere with each other, but join into one smoothly flowing whole when the main passage is reached.

During the exhaust stroke, the steam, as it flows from the cylinder to the valve, is divided by the ribs into a number of equal streams, one to each port in the bushing.

Absence of all quick turns, and other baffling obstructions, speeds up the flow of steam, so that an 8 or 10 inch valve gives a higher initial pressure and a better admission line than can be obtained with the ordinary design of port with a fourteen or sixteen inch valve.

Use of a small valve gives the necessary room to employ a properly designed steam port.

Conversely, proper design of port permits the use of a small valve.

INSIDE ADMISSION VALVES

Nearly all piston valves are of the inside admission type, requiring but one size of valve bushing, whereas the outside admission valve used in the older engines had a larger bushing on the valve stem side, although in some cases an extension valve rod was used passing through the forward valve chamber head; in this case both bushings were of equal diameter. The reason for using the two sizes of valve chamber bushings was on account of the area used up by the valve stem; for example, with the outside admission valve steam pressure acts on the outside of the valve heads and since the end having the valve stem will not have as much area (the stem being outside the steam chest) a larger bushing must be used to equalize the pressure on the valve stem end of the valve.

The inside admission piston valve has three decided advantages: It requires a bushing of the same diameter for both ends of the valve, making the work of boring the valve chamber much less and requiring one size of packing rings.

The valve taking steam inside does not exert a heavy pressure on the valve stem packing, adding much to service obtained with the older type.

The inside admission valve exhausting steam at the ends forms a jacket for that steam entering the chest, cutting down somewhat the loss in temperature and using but one single admission port to the steam chest, therefore greatly reducing the total area exposed to the action of the outside temperature.

UNIVERSAL VALVE CHEST

Universal Valve Chests are applicable to any design of slide valve cylinder. They provide the means for superheating old slide valve engines almost as cheaply as those with piston valves. Engines equipped with Universal Valve Chests are as efficient and powerful and more easily maintained than those with piston valve cylinders.

In designing the Valve Chest special care was taken to provide for free unrestricted flow of steam from valve to cylinder. The ports around the valve are 100% effective. Capacity is provided equivalent to the opening through the ports of the old slide valve.

This design gives a small valve, minimizes frictional resistance and reduces the stresses due to reciprocating weights.

This chest is adaptable to either inside or outside admission. It is arranged with a supporting inner valve chamber which is jointed to the valve seat independent of the outer chest which is seated on the cylinder apron in the usual way. Thus, the regular inlet port to steam chest may be utilized.

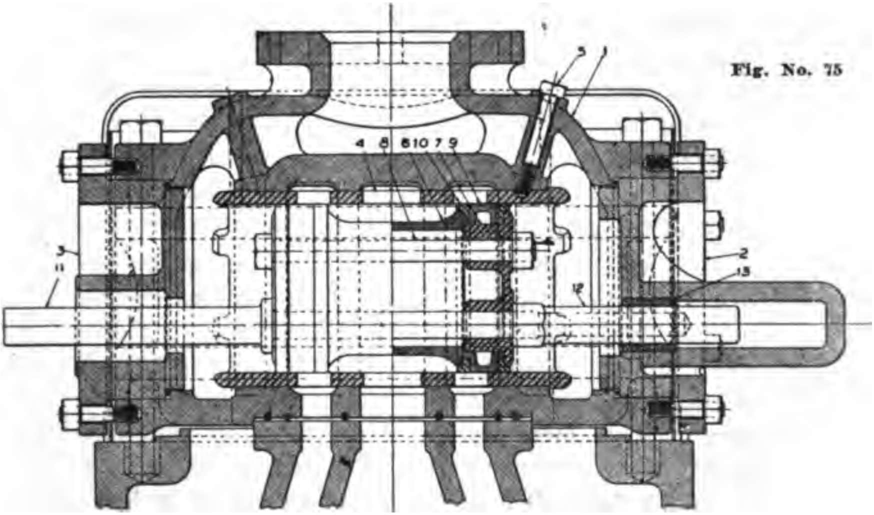


Fig. No. 75

1. Steam Chest.
2. Steam Chest Head (Front).
3. Steam Chest Head (Back).
4. Bushing.
5. Bushing Set Screw.
6. Valve Body.
7. Valve Follower.
8. Valve Follower Bolt.
9. Valve Bull Ring.
10. Valve Packing Rings.
11. Valve Stem.
12. Valve Stem Extension.
13. Valve Stem Extension Bushing.

STEPHENSON GEAR IN GENERAL

The simple slide valve stationary engine has its eccentric located ahead of the crank pin so that the eccentric will push the valve over to open the steam port when the piston reaches the centre, but with the Stephenson gear in locomotive practice it is necessary to place the eccentric on the opposite position and its location is generally overcome by the use of the indirect rocker arm.

When the inside admission valve is applied it moves opposite to the slide valve or outside admission valve; this corrects or overcomes the effect of the eccentric location, but the rocker arm must be made direct. Why? Because the inside admission valve brings the same events as though the eccentric was ahead of the pin and the valve direct or outside admission.

Slide valves should be given generous steam or outside lap in order to provide for large exhaust opening under the valve when working at short cut off. For example—assume a valve having outside lap of one inch and assume the maximum opening of the port to be ⅜ inches at the shortest cut off, now assume one-quarter of an inch be added to the outside lap, the valve will have to be moved back ¼ inch more to give the steam port opening, the result being an increased exhaust opening and a much freer running engine.

Of course the above is given as a rough example; lap could not be given to the valve without changing the valve gear to accomplish the same result as before.

The maximum cut off or point of the stroke where the steam passing from the boiler to the cylinders is cut off, ranges 85%; that is, the steam entering the cylinders can be cut off at 25½ inches for maximum when the stroke of the piston is 30 inches.

When a slide or piston valve is made to cut off earlier by changing the angle of advance (moving the eccentric in the direction the engine is to run under the influence of that eccentric) or hooking up the reverse lever all events of the stroke are earlier. This operation produces earlier closing of the exhaust port and hence much greater compression, and since compression when allowed to run too high retards the movement of the piston and often in slide valves produces sufficient pressure to lift them from their seats causing a blow direct into the exhaust port. It is customary to increase the exhaust opening by taking off some metal from the exhaust edges of the valve, giving it what is known as exhaust clearance, to overcome this condition. Nearly all modern locomotives have exhaust clearance, generally running from 0 to 1/64 of an inch in slow freight engines to ¼ inch for fast passenger locomotives. Exhaust lap is not used to any extent on modern passenger locomotives because of the excessive compression produced. It is desirable to have a large exhaust port opening especially at short cut off, and since the exhaust lap decreases this opening it is not used.

The slide valve and outside admission piston valves should have a travel equal to twice the lap plus the width of both steam ports and ¼ inch added.

The valve gear should be designed to produce early cut off so that the exhaust opening will not have too large a volume of steam to handle. For example—assume the minimum cut off is ten inches on an engine having a 30 inch stroke the throttle will have to be partially closed to regulate the speed on light trains in this case, making it necessary for the restricted exhaust opening to handle a large volume of steam making the engine logy and expensive in fuel consumption.

ANGULARITY OF THE MAIN ROD

Referring to Fig. 76, the stroke of the piston is shown by the arrows.

Assume the crank pin to travel in a straight line.

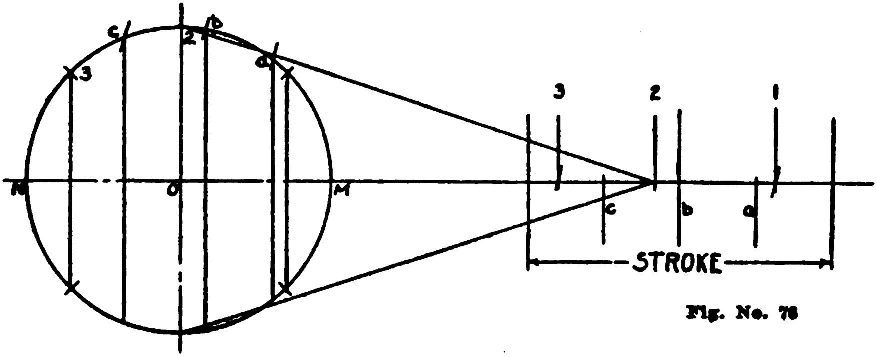


Fig. No. 76

Should the crosshead be at its beginning point of the stroke on the guides, the crank pin would be at M and when the crosshead is at B the crank pin would be at O, when the crosshead reached the end of the stroke the main pin would be at N.

Assume the crank pin to travel in a circle as it does, starting back from the beginning point of stroke on the guides, the crank pin is at M; when the crosshead reaches B on the guides the pin will be at B on the wheel; here we see there is a lead to the crosshead. For example—the piston has made half of it a stroke but the main pin has not reached half of its travel; this distance is increased on account of the rod angle. Now, when the piston passes by its mid stroke to position 2 the main pin is at position 2 of the circle. It will be noticed right here the crosshead must run faster than the main pin, and this distance is shown by the lines on the guides between line B and line 2 above.

When the crosshead reaches C on the guides the main pin is at C on the wheel; also the positions are 3 on the guides, and 3 on the wheel for the crank pin, on the next division. When the end of the stroke is reached of course the main pin is at N.

It will be seen by dropping the lines down from the circle to cross or intersect the line N-M the speeds of the crosshead must vary, as shown by the relative distances between the divisions on N and M.

On the return stroke it will be seen there will be a lag to the crosshead as compared with the main pin. For example—when the crosshead reaches line 2 on the guides (behind its middle point) the crank pin will be at its mid travel at line 2 on the circle.

It is evident then that there must be some provision made to hasten or delay the valve movement in order to overcome some of this irregularity of steam distribution occasioned by the main rod angularity, and is provided for as described in the foregoing pages on the link saddle pin location.

We might explain the angularity of the main rod in another way.

For example—assume an engine with the main rod disconnected and an eight-foot main rod and stroke of 28 inches, and assume the crosshead to stand in the middle of its travel on the guides. In this position the centre of the back end of the main rod strap with brasses in position would equal the distance between the centre of the wrist pin and the centre of the axle. Then to find the distance the crosshead must be moved connect the main rod onto the main pin when the engine stands either on the top or bottom quarter you will find cannot be done without moving the crosshead back to make up the extra distance because of the angle assumed by the rod. In the above case the crosshead would have to be moved back 1½ inches before it could be connected up.

The longer the main rod can be made, of course, the less will be the effect of angularity.

CAUSES FOR ENGINES SOUNDING OUT OF SQUARE

Stephenson Valve Gear

Loose eccentric cams at keyway on axles.

Slipped eccentric blades causing one eccentric blade or rod to become longer than the others. Worn link block pins causing the slack to be taken up before the rocker arm and valve rod can be moved.

Worn rocker boxes having excessive slack.

Worn eccentric straps.

Link hangers not of the same length.

Tumbling shaft not setting level on the frame or loose; this will make one link hanger hold the link up more on one side than on the other, the lower of the two will cause that side of the engine to be worked at longer cut off in forward gear and short in the back gear.

Loose valve rod keys or rocker arm pin worn.

Cases have been known where a cylinder bushing became loose and slipped around, closing a portion of the steam ports so that the admission of steam to the cylinders was restricted. This caused the engine to sound out of square.

Many defective valve gears are traced to the improper length of the reach rod. This will cause the link to stand too high or too low from the link block when the engine is in full gear.

To determine the proper length plumb the reverse lever and see if the reverse arm of the tumbling shaft is plumb; if not a correction should be made in its length to bring both in a vertical position.

Slack wedges worn driving boxes will cause an engine to sound out of square, particularly when the slack is on one side only.

Engines run without proper valve lubrication will often sound out of square because the excessive strain put on the valve gear may cause buckling of eccentric and reach rods.

Improperly set eccentric cams sometimes cause trouble; defects of this kind can be remedied by use of offset keys to bring the eccentric to the proper position.

The total slack in the valve gear can be determined by use of a bar placed to one side of the rocker arm and prying it first ahead and then back; the total slack can then be measured from the valve stem stuffing box, making a mark as the stem is moved to the extreme front and back positions.

Some of the older types of engines can be squared in the forward gear by changing the turnbuckle on the valve rod or using a key and shim; this practice is not recommended because it will throw the engine out in the back gear; the real cause should be found and the proper remedy applied.

SETTING VALVES ON THE STEPHENSON GEAR

The relative positions of the eccentric are in general 90 degrees ahead or behind the main pin. For example—when running ahead, the forward motion eccentric follows the main pin 90 degrees less the lap and lead of the valve. When backing up the same is true of the backing up eccentric. The above is true when the indirect rocker arm is used or when the inside admission valve and direct rocker arm are used in combination.

Modern valve gears are designed to give a variable lead since it requires more lead; at short cut off the eccentric location is almost universal.

There may be, however, some locomotives with the eccentrics set to lead the pin in the running direction, but the chief disadvantage is that lead does not increase with the shortened cut off and therefore are undesirable.

FINDING THE DEAD CENTRE

Refer to Fig. 22 showing the method for finding the dead centre with any type of valve gear.

TO FIND THE PORT MARKS

Often engines will be found to have port marks that are improperly located on the valve rod. To check the port marks on a slide valve engine proceed as follows:

Take up lost motion between the valve yoke and valve, if any; insert the valve stem key at its proper position.

Make a prick punch mark on the cylinder to set the straight end of the valve tram against; draw a parallel line on the valve rod as shown in Fig. 92.

Move the valve back until the steam port is open 1/64 of an inch; scribe an arc on the horizontal line on the valve rod with the tram set against the cylinder or steam chest. Move the valve ahead until the back port is open the same amount and scribe another arc on the horizontal line; then with a prick punch make marks; these will show the opening points of the valve.

After the opening marks are made, the centre position of the valve can be determined by accurately dividing the distance between the two marks, and here a prick punch mark should be made on the horizontal line.

The marks so made on the valve stem show the cut off points of the valve and the middle mark (should the engine have no inside lap or clearance) will show the points of compression and release.

If the valve has inside clearance or inside lap take a pair of dividers and scribe a circle from the middle mark having the width of the opening of the compasses equal to the exhaust clearance or lap on one port. At the point where the circle cuts the line will show the points of release or when compression takes place.

PORT MARKS AND LEAD

Lead will be measured as the distance outside the port marks, that is, it will be ahead of the front port mark and back of the back port mark.

The lead is changed by moving the eccentric, but it also can be changed by lifting the tumbling shaft or shortening the length of the link hangers; this will take off or put on lead to the other eccentrics, and the opposite motion will be thrown out the amount they are so changed.

EQUALIZING LEAD

The lead is increased by revolving the eccentric on the shaft in the running direction, or made later by moving it back in the opposite direction.

When the lead is unequal lengthening or shortening the eccentric rod is the proper remedy.

Lead can be increased by use of offset keys; this will set the eccentric cam ahead and make all events of the stroke earlier.

After the lead is equalized the reverse lever should be hooked up in the running notch and the cut off tried there. (The approximate cut off will be about one-third the stroke.)

Should cut off be unequal the trouble may be located in the following places: The link hangers may be too short or long, the tumbling shaft too high or a rocker box higher than the other; it is also possible that a link saddle is put on upside down.

Scribing tram marks on the valve stem, use the upper side of the horizontal line for forward motion and the lower for the back motion.

Equalizing cut off make this adjustment on the eccentric rods lengthening or shortening; do not make changes on the valve rod; to do so will throw the valves out in the back gear.

The desired lead having been determined and the valve port mark falls short or long with the tram in position, the eccentric rod must be lengthened or shortened and the following should be observed: For example, assuming the valve travels too far ahead and short back: with an indirect rocker arm the eccentric rod should be lengthened the amount it is so lengthened will depend on the distance the valve is to be moved back from its forward or back position and whether the top rocker arm is the same length as the bottom. Assuming both rocker arms are of the same length and the valve to be moved back ⅛ of an inch, the eccentric rod should be lengthened that amount because the bottom arm moves indirect (opposite) to the top. This is often mistaken. Then assume the rocker arms are not of the same length, the top is 12 inches while the lower is 10 inches; if we multiply the length of the bottom rocker arm and the amount the valve is to be moved together and divide this by the top rocker arm it will show the distance the rod must be moved to give the desired change of valve position. With the direct rocker arm the movement being direct the eccentric rods will move the valve directly as they are shortened or lengthened.

WHAT THE CUT OFF SHOULD BE.

The maximum cut off is generally 85 to 87 per cent. of the piston stroke. The valves may cut off equal in the corner and yet when the lever is hooked up in the running notch the cut off may come unequal on both ends; if this inequality is slight it is preferable to lengthen or shorten the eccentric rod and secure correct distribution of steam in the running notch even at the expense of throwing the valves out in full gear.

VALVE TRAVEL

The valve travel with the reverse lever in central position should be equal to the angular of advance with the amount of lead added. In central position of the reverse lever the lead should be ¼ to ⅜ inches.

In addition to the methods for determining lap at the beginning of this chapter, the port marks give the amount of outside steam lap the valve has, but of course half the amount measured from the middle point of the port marks shows the lap on each side.

A discussion will be taken up further on applied to modern valve gears.

THE WALSCHAERT VALVE GEAR

The reliability of the Walschaert Valve Motion on locomotives, when properly applied, has practically put the former standard (the Stephenson Motion) out of use. It is, therefore, considered that a complete explanation of the theory of this gear, as applied in practice, is desirable.

Like any other device, the Walschaert valve motion is a development of some more simple form. A clear understanding of the underlying principles of this valve gear is, therefore, best obtained by starting with the original form and tracing the various steps in the development.

Fig. 77 represents a simple form of valve motion. This consists of a single crank eccentric, driving a plain valve without lap or lead, by means of an eccentric rod directly connected to the valve stem. Assume that the engine is to run forward; with the main pin on the back centre, as shown, the eccentric crank pin must be on the top quarter. The valve will then be in a central position on its seat with all ports closed. The engine could not, therefore, start of itself when the throttle was opened. Connect another engine of the same kind to the wheel on the other end of the axle. If, then, the main pins are set at right angles to each other, as in the case of the

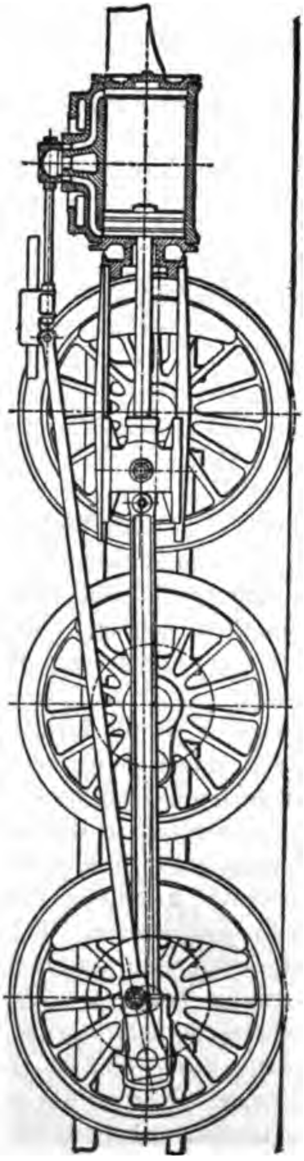


Fig. No. 77

locomotive, the valve of the left hand engine would be in a position to admit steam behind its piston and start the engine forward. The eccentric crank of the engine shown in the illustration would then move its valve forward. This would uncover the back steam port and admit steam behind the piston.

Such an engine, however, would run in only one direction. If, for example, the wheel was pinched backward to start the engine backward; with the eccentric crank in the position shown, the valve would be moved back. Steam would be admitted ahead of instead of behind the piston.

In order to make the engine run backward, the eccentric would have to be on the lower quarter. In such a case, if the wheel was turned to the left or backward, the eccentric would be a quarter of a revolution ahead of the main pin. It would thus move the valve forward, opening up the back port and admitting steam behind the piston.

The introduction of some means for reversing is the first step necessary in the development of this simple form of engine. This can be accomplished by introducing between the eccentric crank and the valve stem a beam pivoted at its centre as shown in Figure 78. Here the link is the beam.

Referring to Diagram "A," Figure 78, with the valve stem connected to the lower end of the link and the main pin on the upper quarter, the valve is in the position to start the engine forward. Assume, on the other hand, that the main pin and eccentric crank remain in the same positions and the valve stem is con-

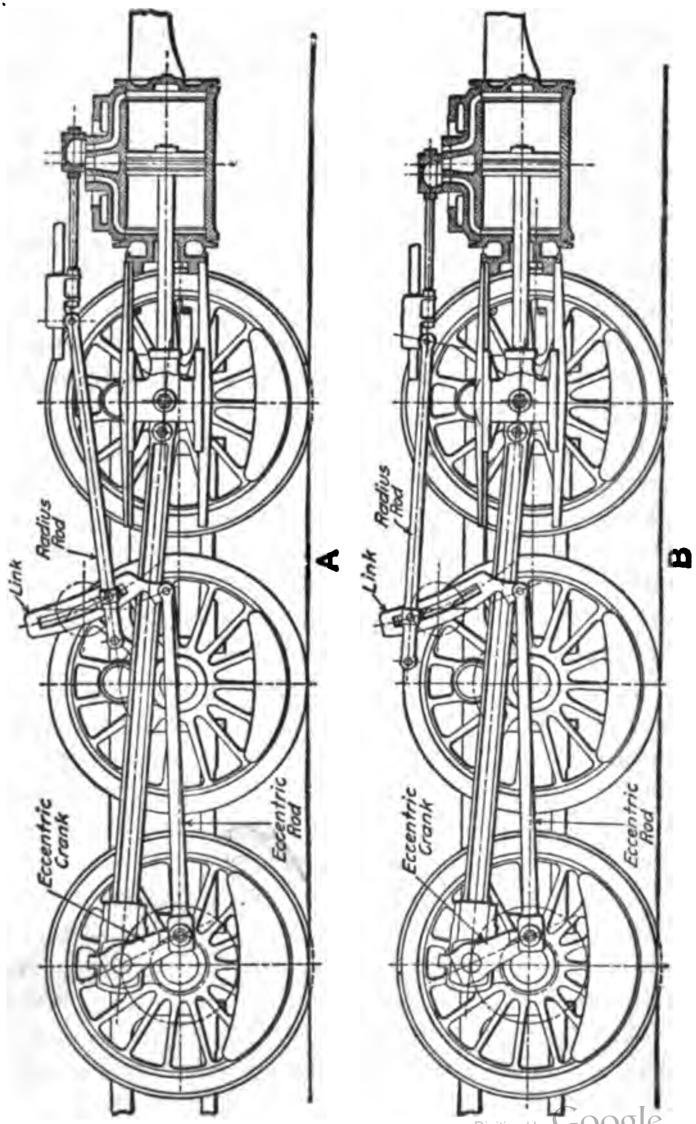

Link
Radius Rod
Eccentric Crank
Eccentric Rod
A
Link
Radius Rod
Eccentric Crank
Eccentric Rod
B

Fig. No. 78

nected to the upper end of the link, as shown in Diagram "B." The valve is then in its extreme position to the left. When the throttle is opened, the engine will run backward. It is evident, then, that a radius rod connected to a block which slides in a curved slot in the link, as shown in the diagram, and the necessary mechanism for raising and lowering the block would give an engine which could be reversed.

The engine, however, is far from an efficient machine. The valve does not close the admission port until the main pin is on the centre at which time the valve is in its central position on the seat. Steam will thus be admitted to the cylinders throughout the full stroke of the piston, irrespective of the travel of the valve.

In order to govern the period for the admission of steam; or, in other words, to change the cut off, a different design of valve must be used. The valve must be given lap. The lap of a valve is that portion of it which overlaps the steam ports when it is on its central position on the seat. Also, the valve should have lead," at least at the ordinary running cut off. Lead is the width of the opening of the steam port given by the valve when the piston is at the beginning of its stroke.

If lap and lead are given to the valve, the valve motion shown in Figure 78 must be so modified that, when the crank pin is on either of the centres, the valve will be advanced a distance equal to the lap plus the lead.

In the Walschaert valve gear, the motion for pro-

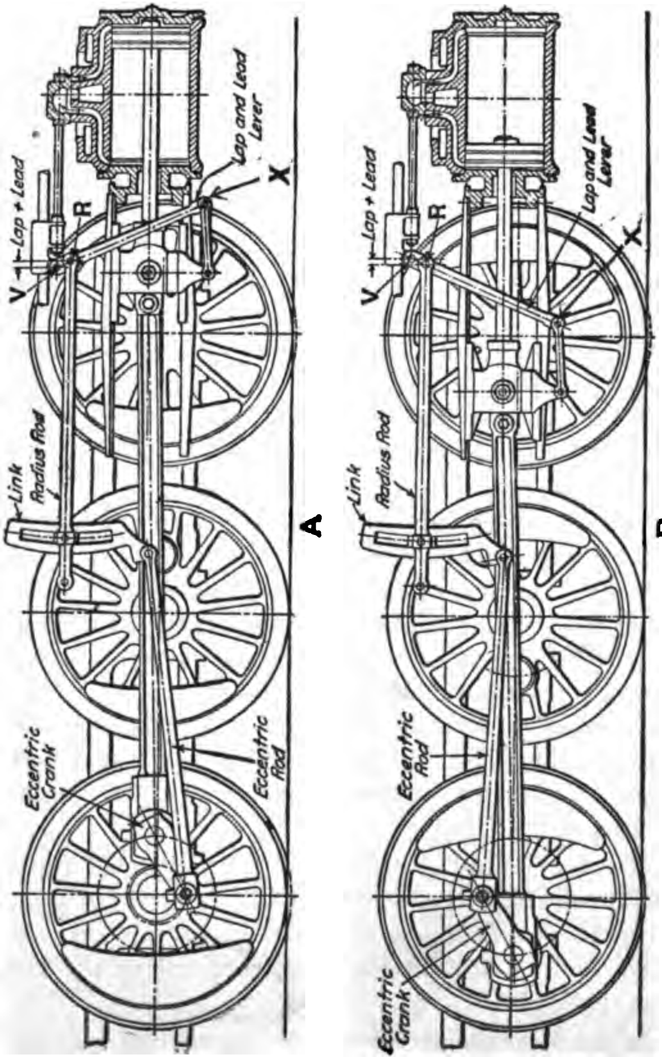

V
Lap + Lead
R
Lap and Lead Lever
X
Link
Radius Rod
A
Eccentric Crank
Eccentric Rod
V
Lap + Lead
R
Lap and Lead Lever
X
Link
Radius Rod
B
Eccentric Rod
Eccentric Crank

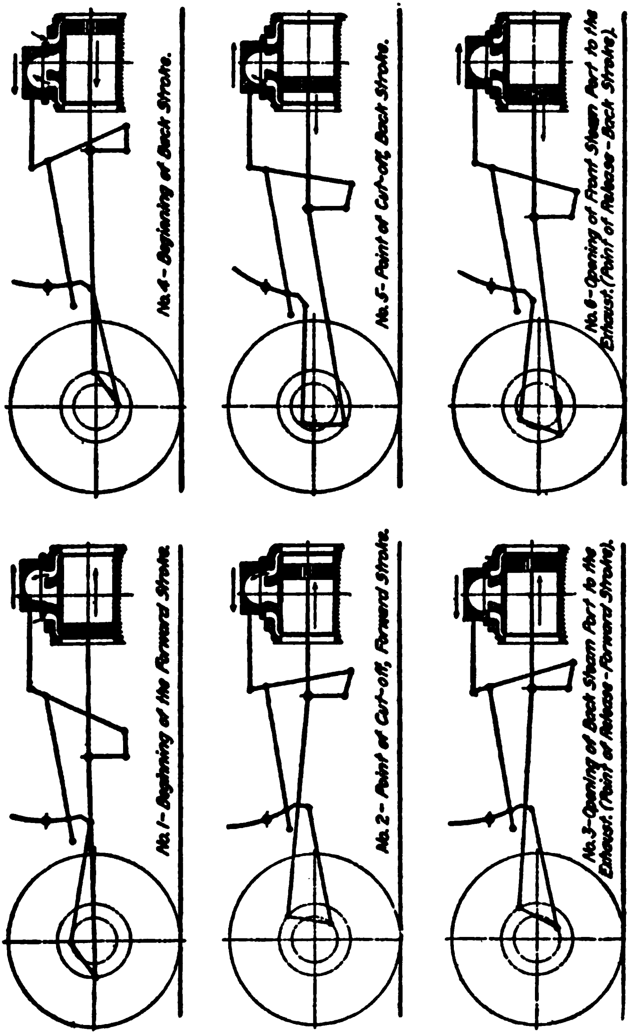
Fig. No. 79

viding lap and lead to the valve is derived from the main pin through the lap and lead lever, which is connected to the crosshead.

The introduction of the lap and lead lever is the next step in the development of the Walschaert valve gear. Referring to Figure 79: when the link block is in the centre of the link, as in diagram "A," there will be no movement of the radius rod as the link is swung back and forth by the eccentric. Assume that the radius rod is connected with the lap and lead lever at the point "R." Also assume that the upper end of the lever is connected with the valve stem crosshead at "V," and the lower end to the crosshead arm by a short link, as shown. With such a construction, as the crosshead moves back and forth, point "R" being stationary, the point "V" will rotate about it. The valve will thus be moved back and forth.

With the main pin on the forward centre, as in diagram "A," the angle assumed by the lap and lead lever has moved the valve back a sufficient distance to uncover the front port. When the main pin is on the back cover, as in diagram "B," the inclination of this lever has opened the back port.

Therefore, the motion of the valve is derived from two distinct sources, viz.: the eccentric crank and the main crank. The former gives the travel to the valve minus the lap and lead. This motion is transmitted through a slotted link oscillating on a fulcrum, in which slot the link block is moved at will above or below the fulcrum. By this means the motion of the engine can be reversed so as to run either forward or



No. 1 - Beginning of the Forward Stroke.

No. 2 - Point of Cut-off, Forward Stroke.

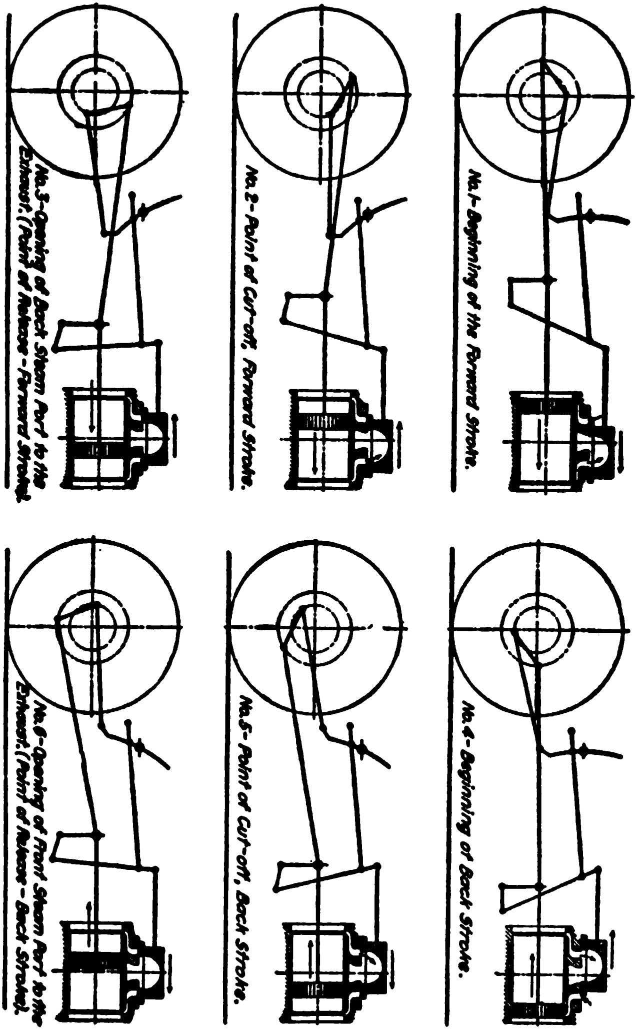
No. 3 - Opening of Back Steam Port to the Exhaust. (Point of Release - Forward Stroke).

No. 4 - Beginning of Back Stroke.

No. 5 - Point of Cut-off, Back Stroke.

No. 6 - Opening of Front Steam Port to the Exhaust. (Point of Release - Back Stroke).

Fig. No. 81



No. 1- Beginning of the Forward Stroke.

No. 2- Point of Cut-off, Forward Stroke.

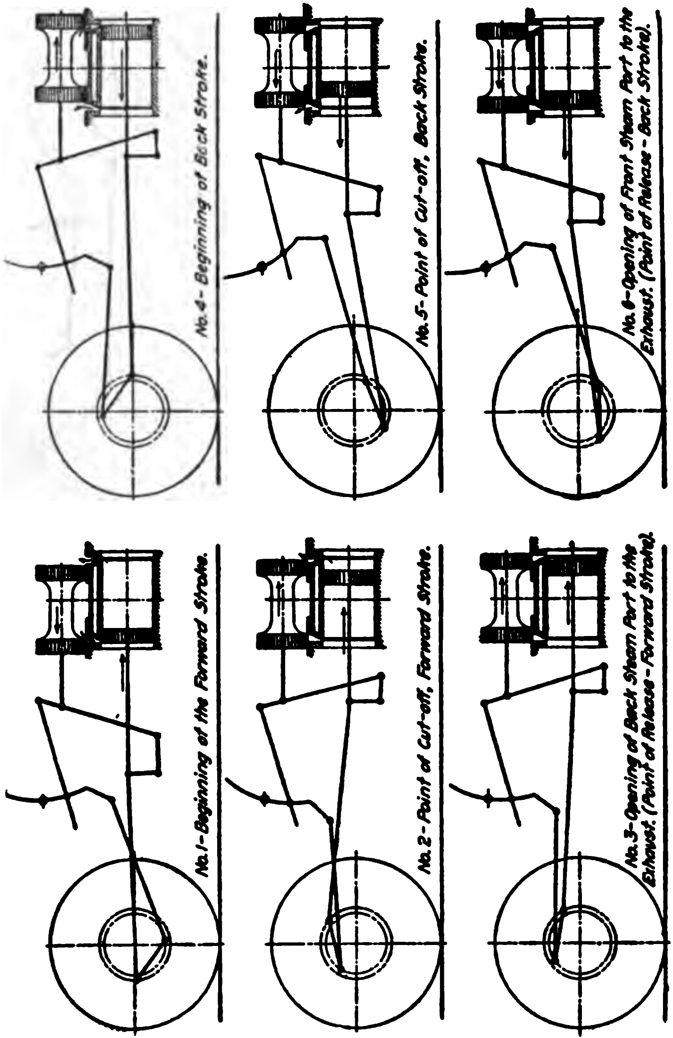
No. 3- Opening of Back Steam Port to the Exhaust. (Point of Release - Forward Stroke).

No. 4- Beginning of Back Stroke.

No. 5- Point of Cut-off, Back Stroke.

No. 6- Opening of Front Steam Port to the Exhaust. (Point of Release - Back Stroke).

Fig. No. 28



No. 1-Beginning of the Forward Stroke.

No. 2-Point of Cut-off, Forward Stroke.

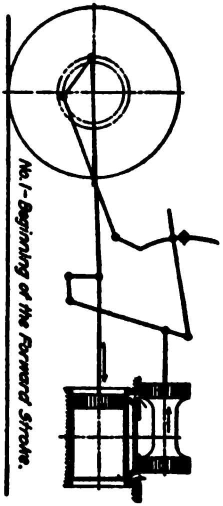
No. 3-Opening of Back Steam Port to the Exhaust. (Point of Release-Forward Stroke).

No. 4-Beginning of Back Stroke.

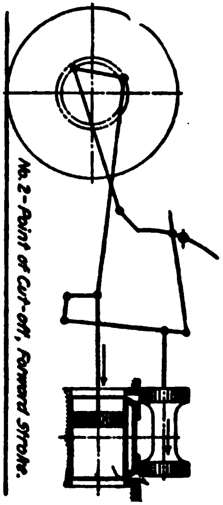
No. 5-Point of Cut-off, Back Stroke.

No. 6-Opening of Front Steam Port to the Exhaust. (Point of Release-Back Stroke).

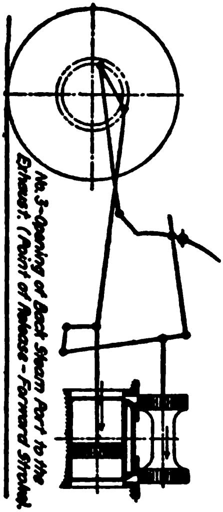
Fig. No. 83



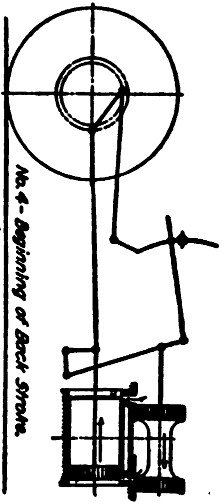
No. 1-Beginning of the Forward Stroke.



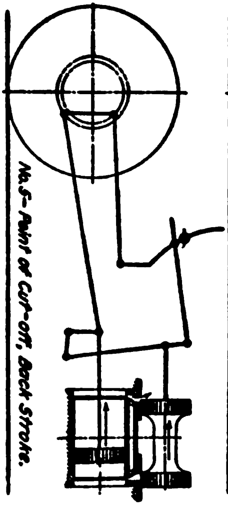
No. 2-Point of Cut-off, Forward Stroke.



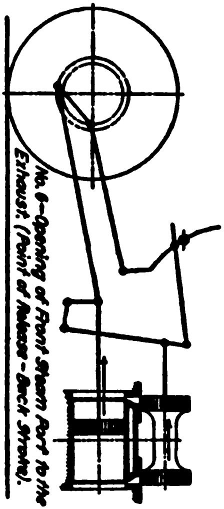
No. 3-Opening of Back Steam Port to the Exhaust. (Point of Release-Forward Stroke).



No. 4-Beginning of Back Stroke.



No. 5-Point of Cut-off, Back Stroke.



No. 6-Opening of Front Steam Port to the Exhaust. (Point of Release-Back Stroke).

Fig. No. 24

backward and it may, therefore, be called the reversing motion of the gear. The lap and lead motion, imparted to the valve by the main crank, is not reversible, as it is symmetrical with relation to the dead centre position of the crank in whichever direction the engine is running and is always constant, regardless of the position of the link block.

The action of the Walschaert valve gear as a whole may be best learned by tracing the movement of the valve through a complete revolution of the wheel. Figures 81 to 84 show a series of diagrams representing different positions of the valve for different positions of the crank pin. For the sake of simplicity, the valve and cylinder are shown in section. The other parts of the gear are represented by their centre lines and centre points only. These diagrams are purposely drawn out of proportion. The valve and the eccentric throw have been enlarged in order to show more clearly the positions of the edges of the valve relative to the edges of the cylinder ports.

In Figure 81, the valve has outside admission; and the motion is represented with the reverse lever in full gear forward. Figure 82 represents the same arrangement of valve motion. In this latter case, however, the reverse lever is hooked up and the engine is cutting off at about 25 per cent. of the stroke.

Figures 83 and 84 represent the Walschaert valve gear as arranged for piston valves having inside admission.

In the Walschaert valve gear, the valve, as previously explained, receives motion from two distinct sources:

First, from the eccentric crank. This gives the valve its full travel.

Second, from the lap and dead lever. This gives the valve its lead. The valve would receive a travel from this source equal to twice the lap plus twice the lead, even if the eccentric rod was disconnected.

Considering diagram 1, Figure 81, the valve has outside admission. Consequently, forward motion being taken from the bottom of the link, the eccentric crank leads the main pin. Also the radius rod is connected to the lap and lead lever below the valve stem.

The link is in its central position. Therefore, the valve would likewise be in its central position, if it were not for the motion given to it by the lap and lead lever. The travel of the crosshead to the back end of the stroke has caused this lever to rotate about its point of connection with the radius rod. This has moved the valve forward, as indicated by the arrow, a distance equal to the lap of the valve plus the lead.

Considering diagram "I," Figure 82, the main pin, eccentric crank, link and crosshead are in the same positions as they are in the corresponding diagram in Figure 81. The link block, however, is nearer the centre of the link. This has not affected the lead for the following reasons: The length of the radius rod is the same as the radius of the link, or approximately so. Thus, as the link is in its central position the raising of the link does not cause any movement of the front end of the radius bar. This point, which is the fulcrum of the lap and lead lever, is in the same position as in the diagram previously considered. Consequently, this lever has moved the valve to the same position as before; and the lead is the same as when the reverse lever was in full gear.

In Figures 83 and 84, the valves have inside admission. The radius rod is thus connected to the lap and lead level above the valve stem.

The diagrams in Figures 81 to 84 represent the various valve events throughout a complete revolution of wheels. Comparison between corresponding diagrams in the four figures brings out very clearly the difference in the arrangement of the Walschaert valve gear for outside and inside admission valves. It also shows the effect on the various valve events of hooking up the reverse lever. For example, it will be noticed that in figures 82 and 84 the valve cuts off the steam from the cylinders and opens the steam ports to the exhaust at a much earlier period in the stroke than it does in Figures 81 and 83. The latter figures represent the engine with the reverse lever in the corner notch; while Figures 82 and 84 represent running with a short cut off.

,With the eccentric crank a quarter of a revolution from the main pin, and with the eccentric rod of such length that the link is in its central position at the end of the stroke, the lead in the Walschaert valve gear is the same for all cut offs.

To change the lead of the Walschaert valve gear, under the conditions given in the preceding paragraph, it is necessary to change either the lap of the valve or the distance between the connecting points of the lap and lead lever. Reducing the lap of the valve increases the lead, and vice versa. Changing the lap also changes the point of cut off. If the lap is reduced, the cut off will occur at a later period in the stroke; while if it is increased the opposite result will occur.

The following rules govern the changes to be made in the lengths of the arms of the lap and lead lever to increase or decrease the lead:

To **increase** the lead, make the upper arm (or distance between the valve stem and radius bar connections) longer in proportion to the lower arm (or distance between the radius rod connection and bottom connection of the lever).

To **decrease** the lead, make the upper arm shorter in proportion to the lower arm of the lever.

ARRANGEMENT

A general outline of the gear for an inside-admission valve is shown in Figure 85, where the names are given of all essential parts. These names define, as nearly as practicable, the special function each one has to perform in the combination of the gear. Starting at the crank pin "D" we have the eccentric crank, eccentric rod, link, radius rod, combination lever, combination link, crosshead arm and link block "g" (indicated only by letter).

Figure 86 is a similar arrangement of an outside-admission gear with no change in the names of any of the working parts.

It will be noted that in Figure 85 the eccentric

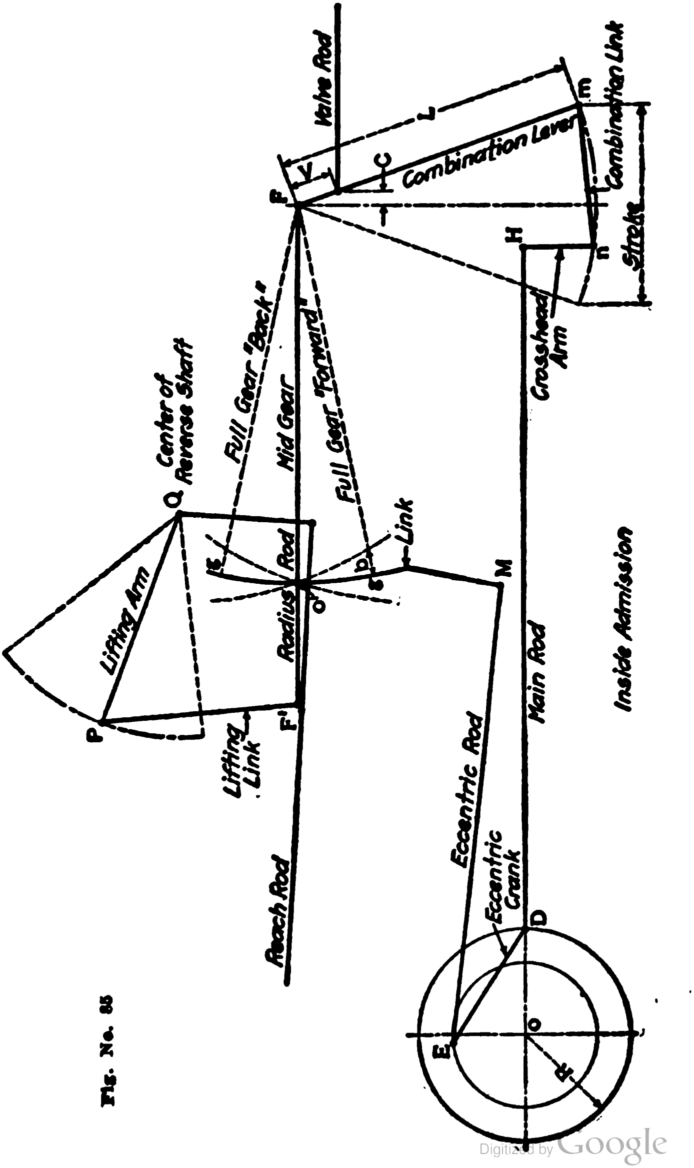
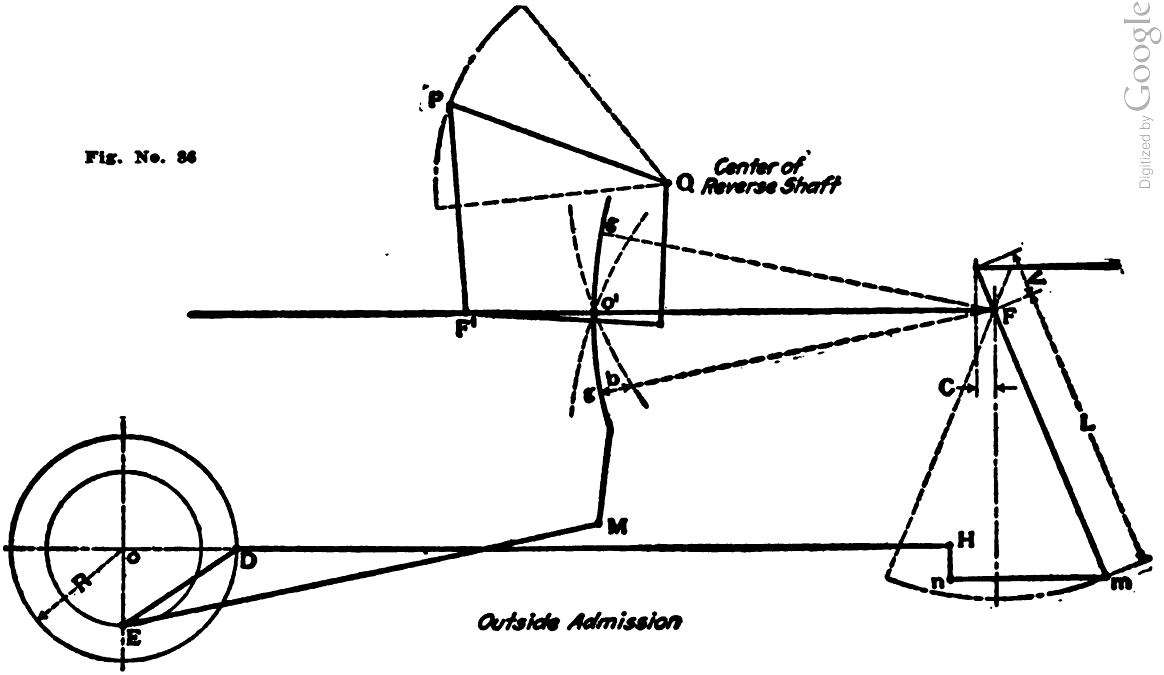

Valve Rod
L
Y
C
F
Combination Lever
m
Combination Link
H
n
Stroke
Crosshead Arm
Full Gear "Back"
Mid Gear
Full Gear "Forward"
Center of Reverse Shaft
Q
Link
M
a
b
O'
Radius Rod
Lifting Arm
P
Lifting Link
F'
Main Rod
Inside Admission
Eccentric Rod
Eccentric Crank
D
O
E
R
Reach Rod

Fig. No. 85

Fig. No. 86


P
Q
Center of Reverse Shaft
g
o'
F'
b
g
C
L
F
H
M
n
m
o
D
R
E
Outside Admission

crank follows the main crank, while in Figure 86 it leads. Also in Figures 85 and 86 the radius bar is shown in the bottom portion of the link in forward motion, thereby reducing the stresses on the link trunnion bearings when running forward.

Before proceeding with the details of the gear, the stroke of the piston, lap and lead, virtual eccentric throw, valve travel and the point of cut off must be known. Of these the stroke, lead, valve travel and cut off are determined with respect to the size of engine. It is advisable to add 1/32 inch to the actually desired lead to provide for wear of pins and bushings.

SETTING THE WALSCHAERT VALVE GEAR

If the gear is properly designed, the setting of the Walschaert valve motion is very simple.

It is essential that the length of the eccentric crank, the lengths of the arms of the lap and lead lever and the length of the lap and lead lever connector should check exactly with the drawings.

No change from the drawings in any of the above parts should be made.

Assuming that all the parts check with the drawings, any adjustments which may be necessary to square the motion should be made in the lengths of the eccentric rod, radius bar or valve stem.

Diagrams "A" and "B," Figure 87, illustrate respectively the effects on the position of the valve resulting from changes in the lengths of the radius rod and eccentric rod.

It is apparent from diagram "A" that any change in the length of the radius rod "R" will have a corresponding and practically equal result on the position of the valve. That is, if the radius rod is lengthened ⅛ inch the valve will be moved forward on its seat a like amount, or vice versa. Therefore, to move the valve ahead or back any amount, lengthen or shorten the radius bar respectively a like amount.

Reference to diagram "B," Figure 87, shows that the effect of a change in the length of the eccentric rod on the position of the valve depends on whether the link block is in the top or bottom of the link.

The following rules therefore govern:

When forward motion is taken from the **lower half** of the link.

In **forward motion**: to move the valve ahead, lengthen the eccentric rod. To move it back, shorten the eccentric rod.

In **backward motion**: to move the valve ahead, shorten the eccentric rod. To move it back, lengthen the eccentric rod.

When forward motion is taken from the **upper half** of the link.

In **forward motion**: to move the valve back, lengthen the eccentric rod. To move it ahead, shorten the eccentric rod.

In **backward motion**: to move the valve ahead, lengthen the eccentric rod. To move it back, shorten the eccentric rod.

A change in the length of the eccentric rod will not alter the position of the valve a like amount. The two will have approximately the same ratio to each

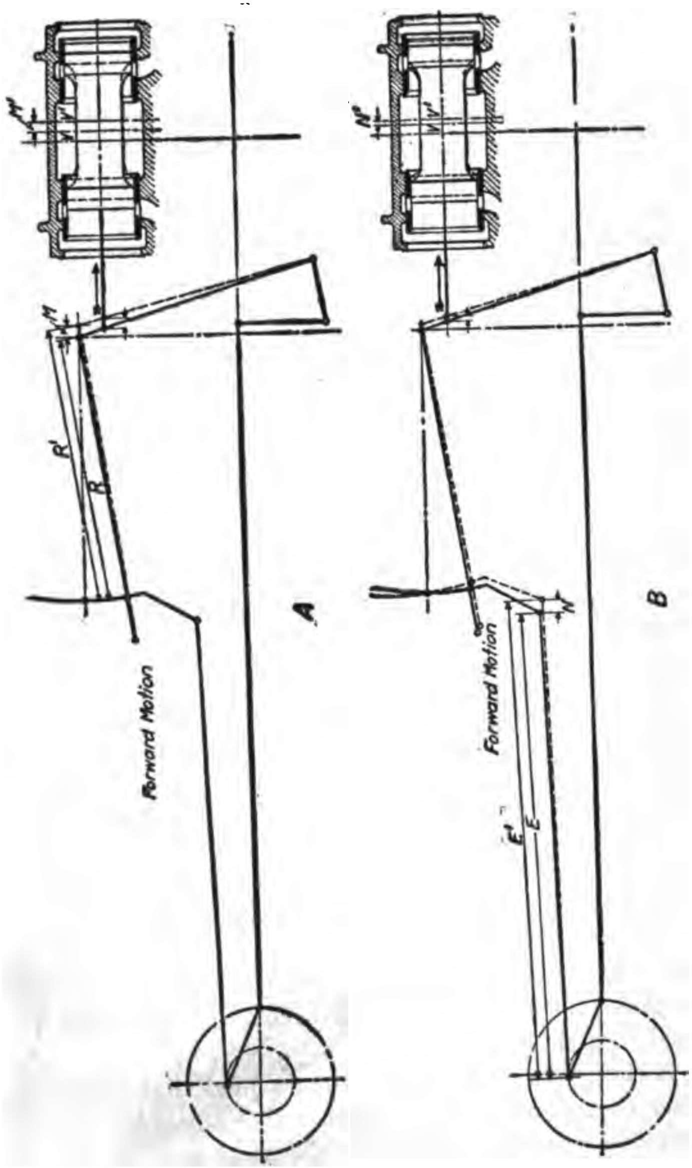


Fig. No. 87

other as that between the eccentric crank throw and the valve travel.

For example: suppose the eccentric throw is 12 inches and the valve travel 6 inches. The ratio is two to one or the latter is one-half of the former. In such a case, a change in the length of the eccentric rod of ⅛ inch would alter the position of the valve only one-half of that amount, or 1/16 inch.

The following method of setting the Walschaert Valve gear is equally applicable to designs having constant lead and those having variable lead:

First: Check the lengths of the eccentric crank, the lap and lead lever, and the lap and lead lever connector.

These dimensions should conform to the drawings and should not be altered.

Second: Raise the main wheels so that the distance from the centre of the wheel to the top of the frame conforms to the amount specified, minus ½ inch for wear of brasses. Then find the dead centres and port marks in the usual manner.

Third: Assemble the gear complete, temporarily tightening the eccentric crank in a position which will give the specified throw.

Fourth: Place the radius bar in the centre of the link. Mark the mid-gear position. Then get the lead at each end of the cylinder. When the lead is constant, the average lead, or the sum of the leads on opposite ends divided by two, should be equal to the specified lead in full gear. When the lead is variable, the average lead in mid-gear position should be equal to one-half of the sum of the specified leads in full forward and full back gear. In other words, it should be the lead due to the lap and lead lever, unaffected by the position of the eccentric crank. Any error in the average lead when the radius bar is in central position is due to an error in the length of the upper or lower arms of the lap and lead lever.

Having thus checked the lengths of the lap and lead lever, equalize the lead by means of the adjusting nuts on the valve stem or by changing the length of the radius bar.

Fifth: Drop the lever into forward gear until the specified travel is obtained. Then, if the average lead is equal to the specified lead in full gear, the eccentric crank is correctly set. If this is not the case, the eccentric crank should be driven one way or the other until the error is corrected. If the average lead is less than the specified lead, the eccentric crank should be driven **inward,** if it **leads** the main pin; and driven **outward,** if it **follows** the main pin. If the average lead is more than the specified lead, the eccentric crank should be driven **outward,** if it **leads** the main pin; and driven **inward** if it **follows** the main pin.

After eccentric crank is correctly set, check valve travel; and relocate full forward position of the reverse lever.

Sixth: If the average lead is correct but unequally divided on the front and back centres, lengthen or shorten the eccentric rod, according to the rules given on this page until it is equalized. It must be borne in mind that to change the lead a given amount the eccentric rod must be changed a greater amount, or about in proportion as the eccentric throw is greater than the valve travel. (See Figure 87.)

Place the reverse lever in a position that will give full travel to back gear, marking this position on the quadrant; and check the lead in the same manner. With variable lead, the full back gear lead should be as much greater than the lead at mid gear as the lead at mid gear is greater than that at full forward gear.

Seventh: Run over the cut offs and obtain other events for as many positions as required. In running over the cut offs of locomotives of the articulated type, obtain the cut offs for each position of the lever for **both engines** before moving the lever to a new position. This is necessary in order that the relative cut offs in high and low pressure cylinders may be compared.

Do not attempt to square cut off at the expense of lead and port opening.

VARIABLE LEAD

Variable lead is brought about by lagging the eccentric back of its 90 degree position and increasing the length of the eccentric rod.

From the foregoing figures, it will be seen that the eccentric rod does not move the valve to give the lead, the lead being produced by the combination lever; but in order to produce lead, the valve must be moved up to a certain position as described in the diagrams; then the combination lever is used to move it still further to make the proper opening. The motion or movement given to the valve by the combination lever is shortened by the link in full gear because the eccentric is back of the normal position, but as the link block is brought up nearer the centre of the link the combination lever has a greater effect on the valve because the moving of the radius bar nearer the centre of the link decreases the movement of the valve under the influence of the eccentric crank.

For example—suppose the valve is moved up to line and line position by the eccentric, there will be no lead opening; now add to the valve ¼ inch lead produced by the combination lever; assuming now the eccentric is moved back so that the combination lever, link and valve is moved back ⅛ of an inch with the engine on the centre and lever in full gear the eccentric will hold the combination lever back in this position. Then, since the eccentric does not move the valve when the link is in the centre of the slot, full lead and lap travel will be given by the combination lever.

It follows, therefore, as we hook up the lever, the influence of the eccentric on the valve is lessened and that of the combination lever increased. This operates to vary the lead, the effect of which is to take off from the lead obtained by the combination lever. This reduction being O when radius bar is in centre of link and an increasing amount as the radius bar is moved toward the forward position.

As this will have the opposite effect or add to the lead as the radius bar is moved toward the backing position the changing lead arrangement is not recommended for switching or engines which are to do a great deal of work backing up.

When working out this arrangement the following points should be kept in mind:

Length of eccentric cranks: As the eccentric is placed at a greater or less angular distance from the crank pin it is necessary to make the eccentric crank of a different length than for constant lead.

Combination lever: No change in the method of proportioning the combination lever is necessary except that its length must be such as to give the lead required when radius bar is in centre of link which will be the mean between lead at full gear front and full gear back.

With the above exceptions all parts are the same as when constant lead is desired.

Setting the valves:

When setting the valves the following method of adjusting should be followed as it will save many unnecessary moves and is equally applicable to Walschaert gear with constant lead.

Place all parts in their proper position as close as possible to the dimensions given on drawing, omitting the permanent fastening of eccentric crank and also of valve stem if valve stem adjustment is provided; then proceed as follows:

1—Put radius bar in centre of link and adjust length so the lead obtained from the combination lever is same front and back, and mark off central position of reverse lever.

2—Put radius bar in full gear forward and check valve travel; also note if the average lead obtained is same as specified.

If valve travel is approximately correct and average lead is long or short, slip the eccentric crank on crank pin to get correct average lead and recheck valve travel; then mark off full forward position of reverse lever.

5—If lead in full gear forward has the correct average but is long or short on either end, correct same by changing the length of eccentric rod.

6—After the above adjustments have been made proceed with the getting of cut off. Preadmission, etc., as called for on valve motion reports.

Adjustment of cut off:

It may be found that there is some difference in the length of cut off for both ends of the cylinder in which case an adjustment of same may be desirable. This can be done by increasing the lead to shorten the cut off or vice versa.

It must be understood, however, that in changing lead to correct cut off a perfectly square cut off should not be aimed at.

Also that changing the lead to correct short cut offs should be done by adjustment of radius bar or valve stem and for long cut offs by adjustment of the eccentric rod.

To determine whether or not the engine has variable lead, proceed as follows: Place the engine on the dead centre, have the reverse lever moved to full forward gear and back to the centre notch of the quadrant. A movement of the valve stem indicates the gear has variable lead.

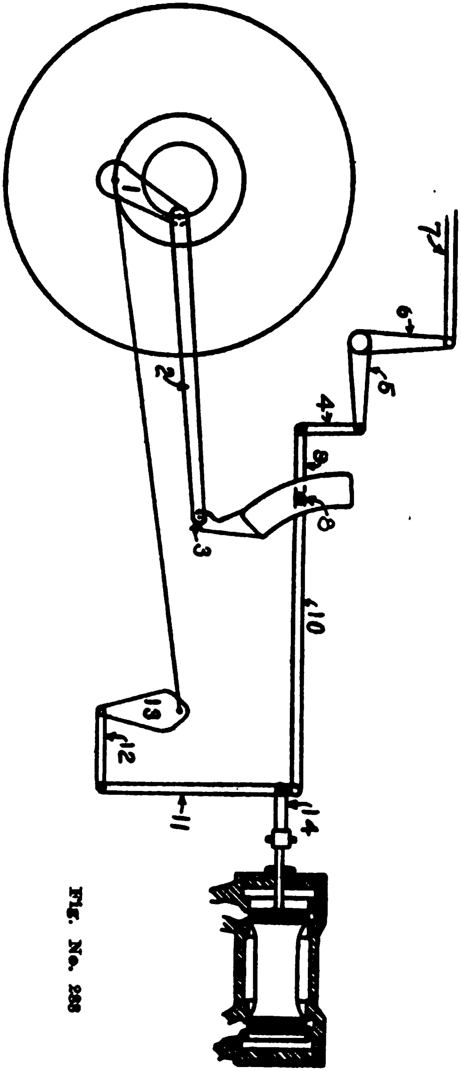


Fig. No. 288

BREAKDOWNS ON WALSCHAERT GEAR

If eccentric crank (1), rod (2), link foot (3), or back end of radius rod (9) breaks, take off broken parts, place reverse lever in central position and block radius rod in link both top and bottom. Disconnect suspension link (4). Proceed.

If suspension link (4) or reverse shaft arm (5) breaks, place reverse lever where engine will start train. Then block link block on disabled side to correspond with link block on good side, placing blocks inside of link slot both top and bottom and do not move reverse lever after starting. Proceed.

Some engines have eccentric arms located ahead of the main pin when running ahead; the following will govern a broken reverse shaft arm (5) or link (4); block the link block above the centre, but when the eccentric follows the main pin block the link block below the centre. The proper position can be determined by placing the reverse lever in forward gear and notice the position of the radius bar on the good side, blocking in a position where the engine will start the train. In all cases slack off on the counterbalance spring and proceed making sure not to block the radius bar up so the engine will be unable to start the train in bad places.

If radius rod (10) breaks forward of link, remove the broken piece from combination lever (11) and take off eccentric rod (2). Clamp valve with a slight port opening, remove or block open the cylinder cocks, increase lubrication on disabled side and thoroughly lubricate bottom guide.

If combination lever (11), union link (12), or crosshead arm (13) breaks disconnect forward end of radius rod (10) and chain same up to clear. Remove eccentric rod (2). If combination lever does not clear wrist pin, fasten it forward or take it off. Clamp valve with a slight port opening, remove or block open cylinder cocks, increase lubrication on disabled side and lubricate bottom guide thoroughly.

If valve stem (14) breaks outside of steam chest, clamp valve with a slight port opening, disconnect forward end of radius rod (10) and chain same up to clear. Remove eccentric rod (2), disconnect union link (12) at crosshead arm and fasten it forward, remove or block open cylinder cocks, increase lubrication on disabled side and lubricate bottom guide thoroughly.

If link block or pin (8) breaks, remove eccentric rod (2), disconnect forward end of radius rod (10), and chain same up to clear. Clamp valve with a slight port opening, remove or block open cylinder cocks, increase lubrication on disabled side and thoroughly lubricate bottom guide.

If valve stem breaks inside of steam chest, place reverse lever in centre position and plumb combination lever (11). Clamp valve stem, take off forward steam chest head and push valve back until it strikes valve stem and block it in this position. Disconnect forward end of radius rod (10) and chain it up to clear. Take off eccentric rod (2), remove or block open cylinder cocks, increase lubrication on disabled side, and thoroughly lubricate bottom guide. Leave port slightly open. Proceed.

It is possible to get an engine into the terminal when the valve stem is broken inside the steam chest, having an inside admission piston valve. For example:—A piston valve will center itself, therefore, the action of the valve rod under the movement given to it by the eccentric will push the valve ahead and as it starts back the steam acting between the valve heads will bring it back to the center, this will cut off the admission of steam to the cylinder and provided the valve has clearance the exhaust port will be open to release the steam from the cylinder as the valve reaches the center. This will give the use of one end of the cylinder on the broken side. The cut-off should be as short as possible in order to get fairly high cylinder compression and more balance to the valve.

If stuck on the center on the good side a start can generally be made by reversing the engine from full forward to full back gear.

To find the central position of the valve quickly for all classes of breakdown, place reverse lever in centre and plumb combination lever.

There are several methods of handling breakdowns on this type of valve gear, but most of them require so much time that the following policy has been adopted by some large railroads having in mind to simplify the matter and reduce the time necessary to make temporary repairs on the road:

BROKEN ECCENTRIC CRANK OR ROD

It is possible to block the link block central and proceed with lap and lead travel of the valve. Having the radius bar in this position will allow the combination or lap and lead lever move the valve the amount of lap plus lead and will assist in lubricating the cylinder, but, however, blocking the link in this manner on the road is a difficult job; it is therefore recommended that the broken parts be removed, the forward end of the radius bar be disconnected and tied up to the running board, and the valve blocked with a little forward steam port opening. Should the engine have by pass valves and direct cylinder lubrication it is well to block the valve central taking care of the cylinder lubrication through the pipe provided for that purpose.

The by pass valves will relieve cylinder compression when drifting but when steam is being worked this can be taken care of by opening the cylinder cocks on the defective side or placing a blind gasket in the steam pipes to the ends of the by pass valves; this will keep the steam pressure away from them and cylinder compression will keep them open.

Of course engines having large inside clearance could be run in without doing any of the above; the only objection would be the tendency to draw the gases from the front end into the cylinder when the engine is shut off.

The combination lever can be left up provided the valve stem is made fast so there will be no tendency for it to move under the force or slap of the lever at high speeds.

BROKEN RADIUS BAR BEHIND THE LINK

It is possible to block the radius bar in a position so the train can be hauled. For example—with the long bell crank type employing a slip block arm the link block can be blocked top and bottom in the link in a position where the cut off will be long enough to insure starting the train on any bad place where the train may stop.

Here we have the difficult job of link blocking again and it is recommended to use the same method described for a broken eccentric rod.

There are many controlling influences, however, to be observed, it being possible under some circumstances when this is but short distance to go. For example—a wire may be used to hold the radius bar in the lower section of the link, having the wire pass around the radius bar and the link foot twisting it up securely to prevent it slipping and working the engine with long cut off and light throttle making it possible to pull the train to its terminal.

Many engines having the Walschaert valve gear will be found with eccentric arm ahead of the main pin; in such a case the radius bar will be above the link centre or trunnion pin. The radius bar should be fastened above in this type, whereas in the lower position in the foregoing type explained.

The same rule is applicable to a broken suspension link or pin.

Should the radius bar become broken ahead of the link proceed the same as explained for a broken eccentric crank or rod.

BROKEN COMBINATION LEVER

When this accident happens the broken parts should be removed and the valve blocked central; the forward end of the radius bar fastened to the running board by use of a chain having it long enough so the radius bar will move freely and not bind the chain.

Often it will not be found possible to secure the radius bar in this manner; in such a case take down the eccentric rod, thus doing away with all motion on the defective side.

BROKEN UNION LINK OR CROSSHEAD ARM

Proceed in the same manner explained for the broken combination lever except taking off the combination lever. For example—tie the lever to the back cylinder cock, clamp the valve central; tie up the radius bar for a short distance to go, but should the distance be great take down the eccentric rod and do not disconnect the forward end of the radius bar when the eccentric rod is taken off.

BROKEN LINK FOOT

Proceed the same as described for a broken eccentric arm or rod.

CAUSES FOR VALVES SOUNDING OUT OF SQUARE WITH THE WALSCHAERT VALVE GEAR

The same causes for sounding out of square in the Stephensen gear apply generally to the Walschaert, as far as the reverse lever tumbling shaft and valve rod connections are concerned.

The most common cause for sounding out of square is excessive wear at the suspension link at the end of the radius bar or slip block arm. The work of moving the valve wears heavily on these pins, imposing considerable load and wear, especially when they are not properly oiled. The tendency of the radius bar is to slip through the link slot when the engine is running. For example—assume the top of the link is moving ahead and the radius bar is above the link trunnion or swinging point, there is a great tendency for the radius bar to slip through the link arc rather than to move the valve; this causes an upward thrust on the suspension link of no little amount, even when the main valves are well lubricated.

The result of this slack moves the link block higher and gives a greater travel ahead, making the cut off longer on that side of the piston receiving steam.

After the engine turns over to cause the eccentric to move the valve in the opposite direction the friction of the valve causes the slack in the radius bar to be taken up, moving it toward the link centre; this makes the valve movement fall short because it brings the radius bar closer to the centre of the link and when the engine is run at very short cut off and the pin having excessive wear the engine will sound badly out of square.

In general, worn valve gears produce wire drawing late admission, no lead, late exhaust and high back pressure.

Often logy engines are traceable to faulty valve setting because it is possible to have the exhaust beats sound square and yet the whole valve gear be improperly set.

The indicator should be occasionally used to check the valve setter, testing the correctness of valve setting by the classes of engines turned out from the repair or back shop.

For example—ten G class engines, five H class, four F class, the letters representing the railroad classification, assuming this to be the shop output in one month. One of each should be indicated for the purpose of checking the valve setter.

To test for slack in the Walschaert gear the same method applies as in the Stephensen type; the slack in the radius bar and suspension link can be measured by prying up the radius bar near the link trunnion having the link standing plumb measuring from the link trunnion centre mark to some point on the radius bar so the wear will be shown in a vertical plane. Much slack will be often found in the reverse lever and latch and many times the reach rod pins will be found worn or the rod itself sprung so that the movement of the valves cause it to buckle slightly under the thrust of the link.

VALVE GEAR DEFECTS AND EFFECT ON FUEL CONSUMPTION

Some of the prominent defects in valve gears and increased fuel required to do the work resulting therefrom.

The maximum cut off in full gear is about 85 per cent. of the stroke for freight engines. Often due to defective valve gears cut off will run up to 87 per cent. making considerable over travel of the valve with late exhaust, no lead and a reduction in the effective pressure on the piston. Defective valve gears of this kind often increase the fuel consumption 15 per cent.

BAKER VALVE GEAR

The Baker Valve Gear is a development of a gear of the same name that has been in use on traction engines for the past fourteen years. The principle of both is the same.

The inventor of the Baker Valve Gear, Mr. Abner D. Baker, of Swanton, Ohio, was granted his first patent on March 3, 1903, which covered the traction engine valve gear.

The first application to a locomotive was made on the Toledo, St. Louis & Western R. R. in 1908, the locomotive valve gear then being known as the Baker-Pilliod. It passed through a period of experiment and was discontinued in 1910, being replaced by the present Baker Locomotive Valve Gear, patents covering which were granted to Mr. Baker on November 14, 1911. This gear is also protected by patents in all of the more important foreign countries.

The Baker Locomotive Valve Gear is now in use on thousands of locomotives and has been adopted as standard by a continually increasing number of railroad companies.

The Baker Valve Gear is an outside gear taking its motion from an eccentric crank attached to the main crank pin and from the main crosshead. It does not use the link and block common to other gears. It consists of an eccentric crank, eccentric rod, valve gear frame (which contains the reverse yoke, radius bars, bell crank and gear connecting rod) valve rod, combination lever and union link, together with the customary reversing arrangement of reach rods, reverse shaft, reverse lever, etc.

The reverse yoke is pivoted in the gear frame and at its upper end is attached to the gear reach rod. In the reverse yoke are pivoted the radius bars, to the lower ends of which the gear connecting rod is attached. This gear connecting rod extends down-

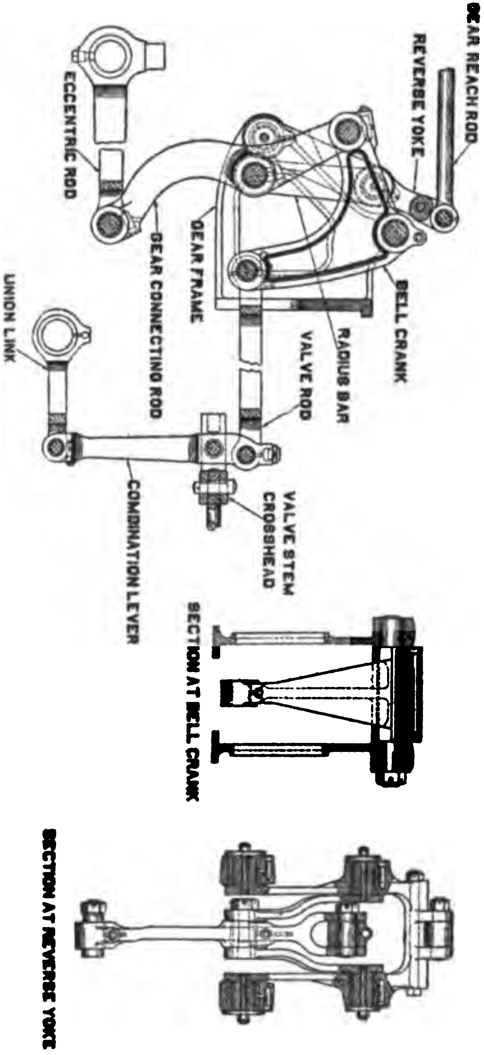


Fig. No. 86 Section Through Baker Valve Gear (inside admission).

ward, connecting with the eccentric rod, and upward, connecting with the bell crank which is pivoted in the gear frame. The motion derived from the

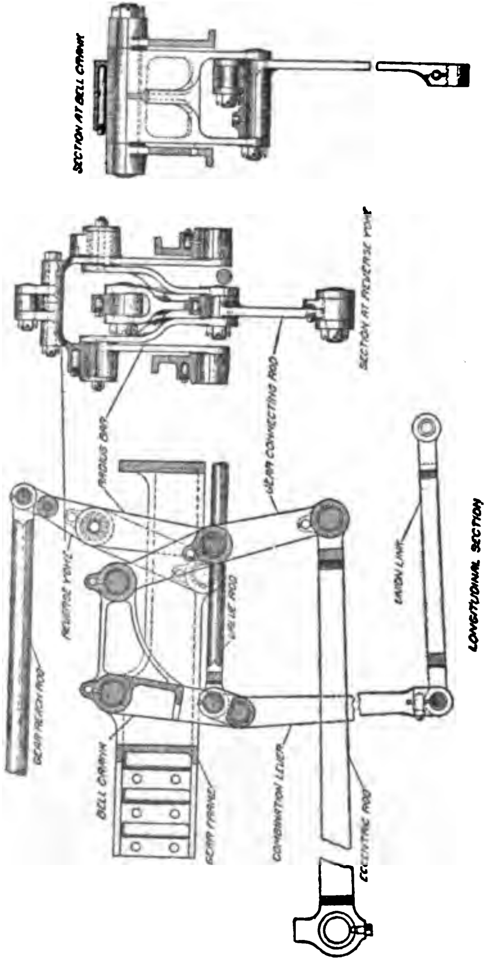


Fig. No. 89. Section Through Baker Valve Gear (outside admission).

eccentric crank (the reversing movement) is carried through the valve gear to the bell crank. It is here combined with the motion of the combination lever (lap and lead movement) and transmitted to the valve by means of the valve rod and valve stem. The combination lever can be attached either to the bell crank or to the valve stem crosshead. The principle is the same in either case.

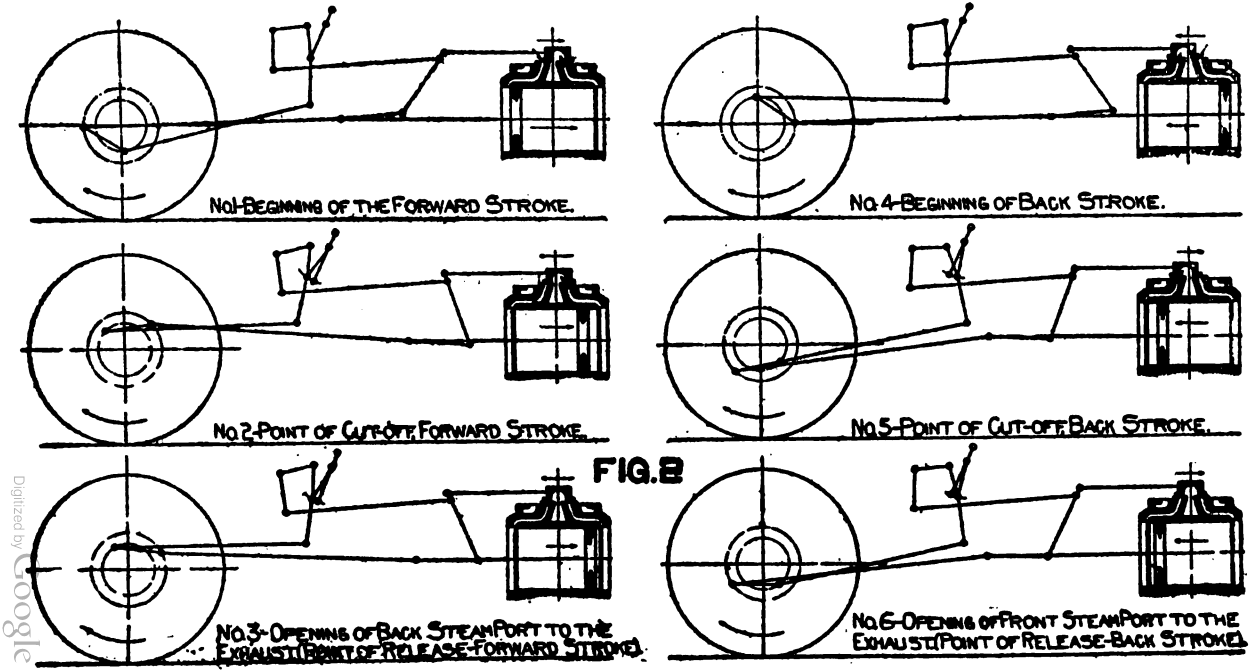
The principal parts of the Baker Valve Gear, the gear frame and contained parts, do not depend upon the gear location for their shape. A standard design can be rigidly adhered to. No change is made in the gear parts for different valve travels, as this is taken care of by proportioning the reverse shaft arms or the reverse lever travel.

PRINCIPLE OF OPERATION

Inside Admission. The action of the Baker Valve Gear may be best learned by tracing the movement of the valve through a complete revolution of the wheels. Figures 2 to 5 shows a series of diagrams representing the different positions of the crank pin. For the sake of simplicity, the valve and cylinder are shown in section. The other parts of the gear are represented by their centre points only. These diagrams are purposely drawn out of proportion. The valve has been enlarged in order to show more clearly the positions of the edges of the valve, relative to the edges of the cylinder ports.

Figures 4 and 5 represent The Baker Valve Gear as arranged for piston valves inside admission.

Forward Motion, Full Stroke. Figure 4, diagram 1, illustrates the engine with the reverse lever in full for-



No. 1—Beginning of the Forward Stroke.

No. 2—Point of Cut-off, Forward Stroke.

No. 3—Opening of Back Steam Port to the Exhaust (Point of Release—Forward Stroke).

No. 4—Beginning of Back Stroke.

No. 5—Point of Cut-off, Back Stroke.

No. 6—Opening of Front Steam Port to the Exhaust (Point of Release—Back Stroke).

FIG. 8

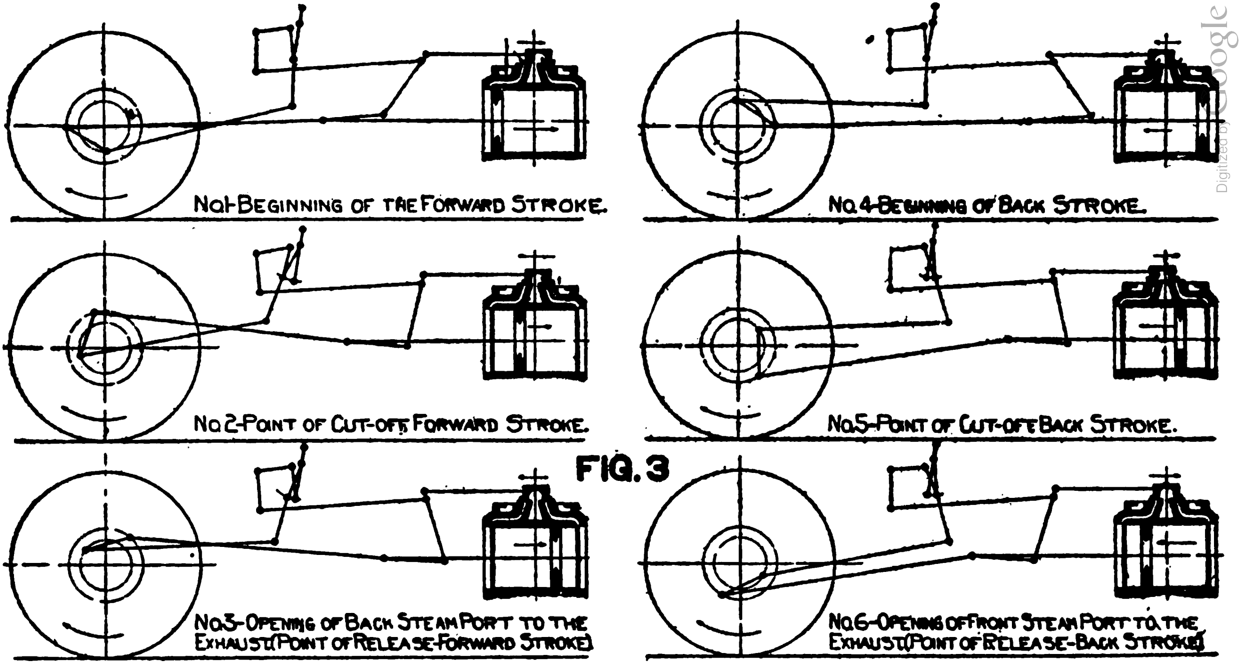


FIG. 3

No. 1-Beginning of the Forward Stroke.

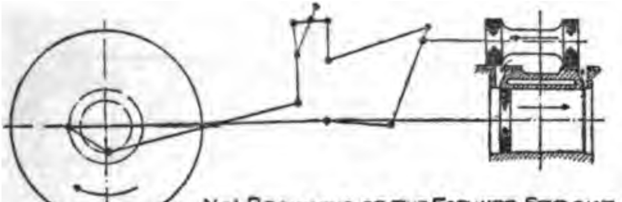
No. 2-Point of Cut-off, Forward Stroke.

No. 3-Opening of Back Steam Port to the Exhaust (Point of Release-Forward Stroke)

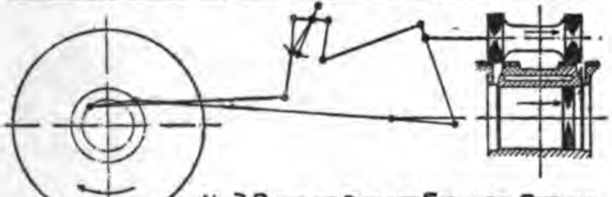
No. 4-Beginning of Back Stroke.

No. 5-Point of Cut-off Back Stroke.

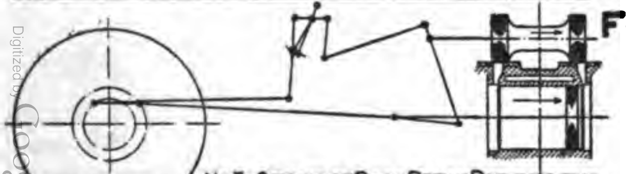
No. 6-Opening of Front Steam Port to the Exhaust (Point of Release-Back Stroke)



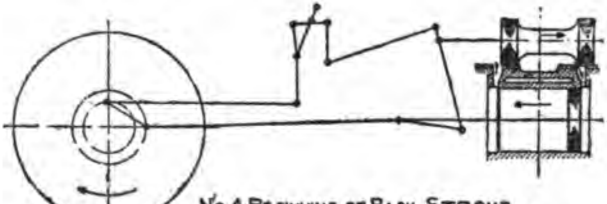
No.1-Beginning of the Forward Stroke.



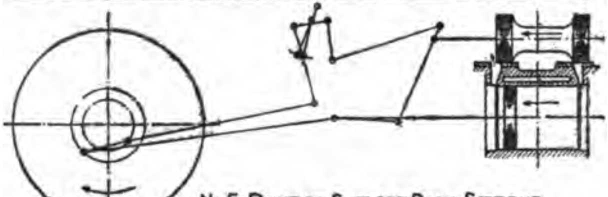
No.2-Point of Cut-off, Forward Stroke.



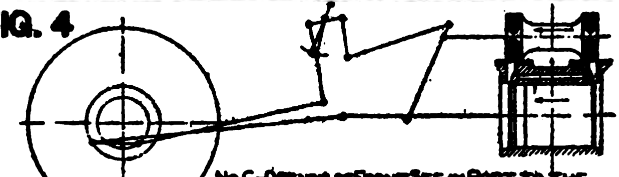
No.3-Opening of Back Steam Port to the Exhaust (Point of Release-Forward Stroke).



No. 4-Beginning of Back Stroke.

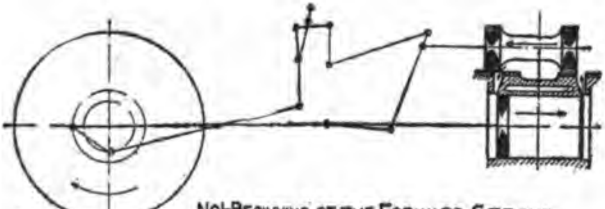


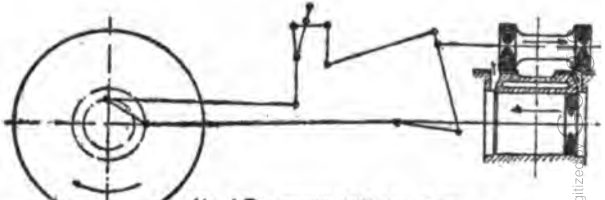
No.5-Point of Cut-off, Back Stroke.

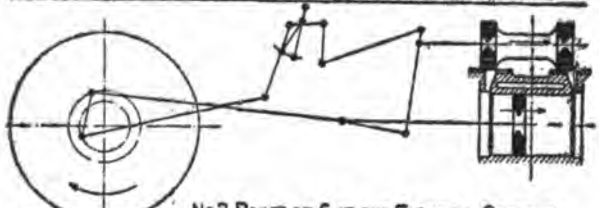


No.6-Opening of Front Steam Port to the Exhaust (Point of Release-Back Stroke).

FIG. 4


NO.1-BEGINNING OF THE FORWARD STROKE.


NO. 4-BEGINNING OF BACK STROKE.


NO.2-POINT OF CUT-OFF FORWARD STROKE.

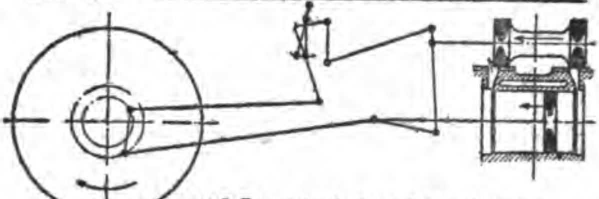
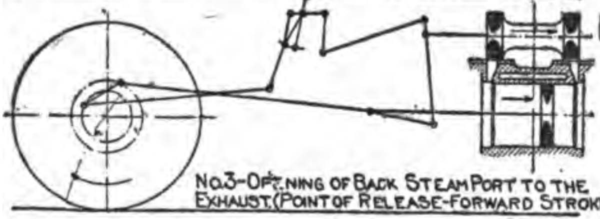
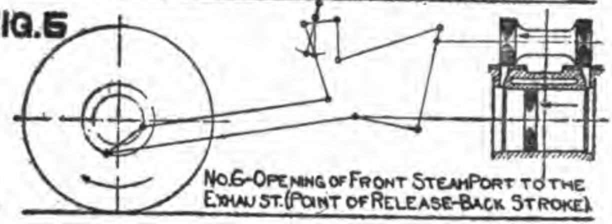

NO.5-POINT OF CUT-OFF, BACK STROKE.

FIG. 6


NO.3-OPENING OF BACK STEAM PORT TO THE EXHAUST. (POINT OF RELEASE-FORWARD STROKE).


NO.6-OPENING OF FRONT STEAM PORT TO THE EXHAUST. (POINT OF RELEASE-BACK STROKE).

ward motion. The engine is represented as being on the back dead centre. As the wheel is rotated in the direction of the arrow, the eccentric rod moves away from the cylinder, carrying with it the gear connecting rod to which it is coupled. This produces a movement of the radius bars also away from the cylinder, which in turn sets up a lifting action on the horizontal arm of the bell crank, thus moving the valve backward. This operation continues until the crank pin practically reaches the top quarter, when the eccentric rod movement reverses (because of the action of the eccentric crank), with the result that the valve starts to close.

Figure 4, diagram 2, shows the valve in the act of closing the rear cylinder port or in the position of crank end Cut off. As the wheel continues to rotate in the direction of the arrow beyond the point shown in diagram 2, the eccentric rod continues to move forward, producing, by means of the gear connecting rod and radius bars, a downward movement on the horizontal arm of the bell crank, thus continuing to move the valve towards the front, until the engine reaches practically the bottom quarter, when the direction of movement of the valve is again reversed in the manner described above. From the description it will be noticed the Baker Valve Gear, inside admission is direct in forward motion; that is, the valve moves in the same direction as the eccentric rod.

Forward Motion Running Positions. The position of the reverse yoke governs the amount of valve travel and also the percentage of cut-off obtained. As the reverse yoke is brought nearer its mid-position the arc of the radius bars becomes more nearly horizontal and produces a less upward and downward movement of the horizontal arm of the ball crank, thus decreasing the valve travel.

Figure 5 shows the engine in the same position as Figure 4, with the exception that the reverse yoke has been brought nearer to the central position, and shows the effect on the various valve events of "hooking up" the reverse yoke. For example, it will be noticed that (in Figure 5) the valve cuts off the steam from the cylinders and opens the ports to the exhaust at a much earlier period in the piston stroke than it does in Figure 4. The latter figure represents the engine with the reverse yoke in the full stroke position, while Figure 5 represents the engine in a shorter Cut off position.

Backward Motion. The reversing of the Baker Valve Gear is accomplished by bringing the radius bar bearings in the reverse yoke past the central position, away from the bell crank. The effect of this is to change the arc of the radius bars. The movement of the eccentric rod away from the cylinder then produces a downward action on the upper arm of the bell crank, causing the valve to move forward. This is just the opposite to the effect of this eccentric rod movement with the reverse yoke in forward motion. The inside admission gear is therefore indirect in back motion; that is, the valve moves in a direction opposite to the movement of the eccentric rod. The "hooking up" is accomplished exactly the same in backward as in forwarod motion.

Mid-Gear Position. The Baker Valve Gear is in mid-position when the radius bar bearings in the reverse yoke are exactly in line with the reverse yoke bearing in the frame and bell crank gear connecting rod bearing.

Outside Admission. The essential difference between the two gears is that in the outside admission gear the reverse yoke is in front of the bell crank and moves away from the bell crank for forward motion, while in the inside admission gears this movement is just the opposite. The eccentric crank location is the same. Figures 2 and 3 represent the Baker Valve Gear, as arranged for slide valve, outside admission. A comparison of these figures with Figures 4 and 5 brings out clearly the difference in arrangement.

Lap and Lead Movement. The lap and lead movement is obtained from the combination lever by simply proportioning this lever so that when its long arm receives a movement equal to the piston stroke, its short arm will deliver to the valve a movement equal to two times the sum of the lap plus the lead. This movement is separate from and entirely independent of the rest of the valve gear action and, therefore, remains constant, regardless of the reverse yoke or the reverse lever position.

To Change the Lead. To change the lead of the Baker Valve Gear, it is necessary to change either the lap of the valve or the distance between the connecting points of the combination lever. Reducing the lap of the valve increases the lead, and vice versa. Changing the lap also changes the points of cut off. The effect of reducing the lap is therefore not only to increase the lead, but also to retard the point of cut off. The effect of increasing the lap will be just the opposite. To increase the lead by means of a change in the combination lever, it is necessary to make the upper arm longer or make the lower arm shorter. To decrease the lead these changes are just the opposite.

Rules. The reverse yoke moves forward in the forward motion.

The eccentric crank follows the main crank pin in the forward motion and leads it in backward motion.

Combination levers for inside admission valves have the valve stem attached below the valve rod connection.

Combination levers for outside admission have the valve stem attached above the valve rod connection.

VALVE SETTING

Object to Be Accomplished. The object to be accomplished is to adjust the valve gear so that Admission, Cut off and Release will occur at correct intervals; that the engine will exert an even, continuous effort and thus be economical in the use or steam. The maximum valve travel, lap, lead and exhaust clearance, are determined by the designer and should not be altered except on proper authority. The best practice is to judge the quality of the valve setting by the uniformity of the Cut offs on front and back on both sides of the engine for any one position of the reverse lever. If the Cut off on both front and back, on both sides of the engine, does not vary in any position of the reverse lever more than ¾", the valve setting may be considered correct.

Recomending Practice. In setting valves it is best to follow a certain definite program, adjusting each part in logical order. The method herein described has been found by The Pilliod Company to be the best adapted to meet all conditions. Experienced valve setters may prefer other methods, but the following is recommended for their consideration:

Operation. In general the operations should follow one another in the manner here submitted:

1st—Assembly.

2nd—Port marks and Dead Centres.

3rd—Location of Eccentric Crank.

4th—Adjustment of Valve Rod and Eccentric Rod.

5th—Adjustment of Full Gear Valve Travels.

6th—Checking of Cut offs; making any slight adjustment to correct same.

7th—Valve Motion Report, when called for.

8th—Application of quadrant stops, aligning of rods, applying nuts, cutter pins, etc., and generally finishing the work.

Assembly. The valve gear should be assembled according to design. The valve, valve seat or bushings, valve stem, combination lever, union link, eccentric crank, reverse shaft arms and gear parts (gear frames, reverse yoke, radius bars, gear conecting rod and bell crank) should be exactly to design and no alterations should be made on any of these parts. Reverse shaft arms and reverse lever or power reversing gear should be placed in mid-gear position and main reach rod made of a length to suit. The main wheel centre should be located at specified distance from top of engine frame. Usually the main wheels are placed on power driven rollers to facilitate their being rotated, and the side rods are not applied.

Trams. A standard valve stem, wheel and crosshead tram should be used on locomotives of the same class,.or as many clases as possible. This will avoid confusion and facilitate the valve setting.

Port Marks. The term "Port Marks" is usually taken to mean lines scribed on the valve stem to show the point of valve opening Admission or closing Cut off on the steam edge. Port Marks made to designate the opening Release and closing Compression of the valve on the exhaust edge are called "Exhaust Port Marks."

Piston valve cylinders are usually provided with peep holes, through which the edge of the valves and of the cylinder ports can be seen. To obtain the port marks: place the steam edge of the valve, line and line with the steam edge of the port in the bushing; with a tram scribe the valve stem as shown in Figure 91. This operation is repeated until the port marks for both front and back ends of valve on both sides of the engine have been obtained.

The exhaust port marks can be obtained in the same way by placing the exhaust edge of the valve, line and line with the exhaust edge of cylinder port in the bushing.

In the case of slide valve cylinders the steam chest covers are usually removed and the port marks obtained the same as above. Here, however, the exhaust port marks must necessarily be laid out, as the

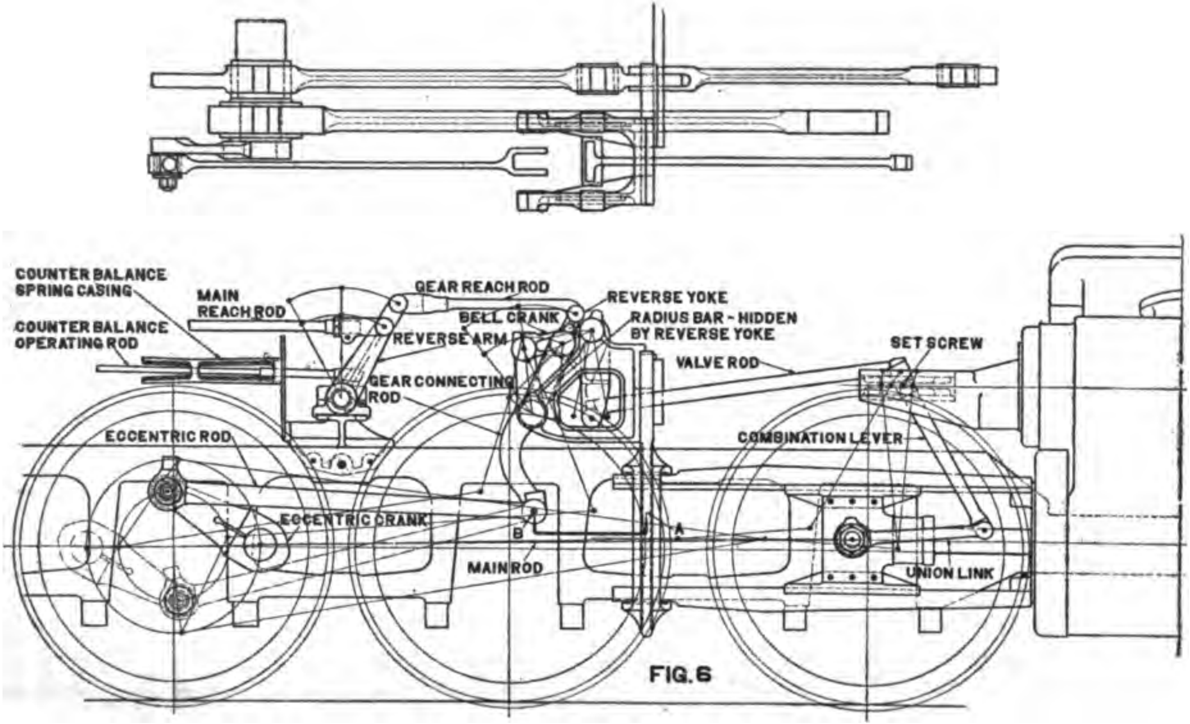

COUNTER BALANCE SPRING CASING
MAIN REACH ROD
COUNTER BALANCE OPERATING ROD
GEAR REACH ROD
BELL CRANK
REVERSE ARM
REVERSE YOKE
RADIUS BAR - HIDDEN BY REVERSE YOKE
SET SCREW
VALVE ROD
GEAR CONNECTING ROD
ECCENTRIC ROD
COMBINATION LEVER
ECCENTRIC CRANK
A
B
MAIN ROD
UNION LINK

FIG. 6

exhaust edges are invisible when the valve is on its seat.

The port marks should be scribed clearly and prick punched for future reference, to avoid confusion with other lines obtained later in the operation of valve setting.

Dead Centres. In order to accurately adjust the valve setting, it is necessary to determine when the piston is exactly at the ends of the stroke. At these points the crosshead wrist pin, main crank pin and the centre of the main journal are in a direct line, so that, no matter how great the pressure in the cylinder, there can be no turning effort produced on the wheel. The engine is therefore, "dead" on that particular side; hence the term Dead Centre. These points are obtained as follows: Rotate the wheel until the crosshead is about one inch from the end of the stroke. With any tram of convenient length from a centre conveniently located on some stationary part as the engine frame, scribe a line across the edge of the driving wheel tire. With the same or another tram, from a centre point on the main crosshead, scribe the guide. Rotate the wheel slowly, holding the crosshead tram in the crosshead mark; the crosshead will move toward the end of the stroke, stop and return. Stop the wheel when the tram drops exactly into the mark on the guide. Mark the driving wheel tire again as above. With a pair of hermaphrodites set about one-half the thickness of the tire, draw a line parallel to the wearing face of the tire so as to cross both of the lines just scribed. With a pair of

Illustrates the Method of Locating Dead Centres.

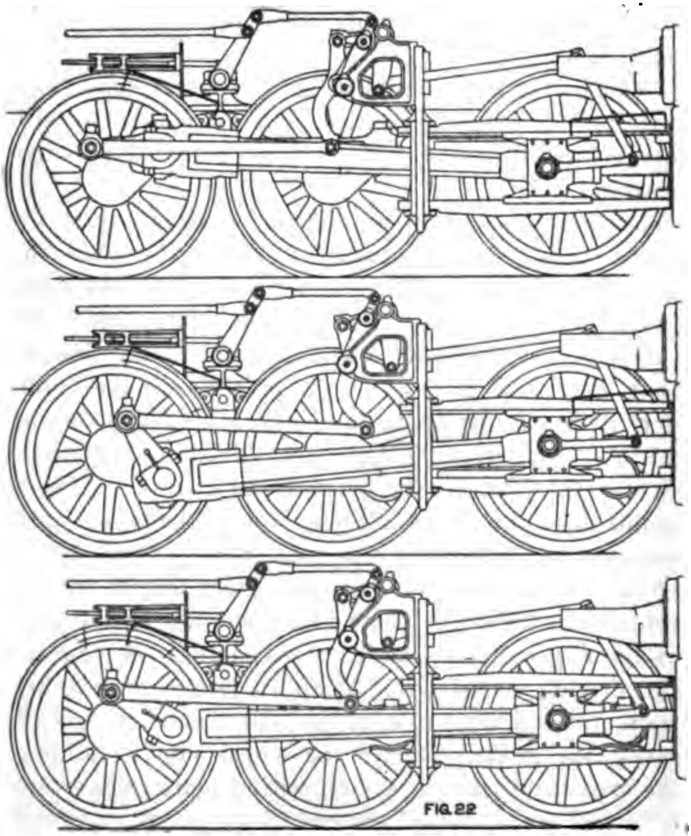


FIG. 22

Fig. No. 22. • **Illustrating the Method of Finding Dead Centres**

dividers, locate a point exactly half way between the two tram lines. Prick punch the last point clearly. When the wheel is set so that the wheel tram drops into this last point, the engine will be on the Dead Centre. The other marks should be erased to avoid confusion.

The effect of the measuring on the crosshead is to find a point where the crosshead travel (from the end of the stroke) is the same, both when approaching, and when leaving, the end of the stroke. By transferring these points to the wheel and dividing them to find the central point, the actual end of the stroke, or Dead Centre, is determined absolutely.

Repeat the above performance until each of the four dead centres have been obtained. (See Figure 22.)

Note: If the wheels are turned by means of power-driven rollers, it is well to locate all the wheel marks on the side occupied by the operator, for his assistance in catching the marks afterward. If there is any slack in the main rod or boxes, the valve setter should absorb all such slack by rolling the wheels so that the main rods will move in the same direction while the marks on the guide are being obtained.

Eccentric Crank Setting. Locate eccentric crank on main crank pin as nearly as possible to specified throw and clamp it temporarily. Catch each of the four dead centres and, with a tram of convenient length, tram from centre of eccentric rod pin to any convenient stationary point, such as the guide or guide yoke. (See Fig. 22.) The scribing is done with the "A" end of the tram, and this should be as nearly on a horizontal line with the front end of the eccentric rod as circumstances will permit. The lines obtained on the front and back dead centre should come exactly together. If they do not, the crank should be moved in the required direction until the lines do come together.

The object to be accomplished is to so locate the eccentric crank that it will (by means of the eccentric rod) place the gear connection rod in exactly the same point on each dead centre. This is essential, for otherwise it is impossible to obtain the same lead condition on both front and back dead centres and in both forward and backward motion. Having set the eccentric crank as explained above, no further change should be required, and it can be permanently secured.

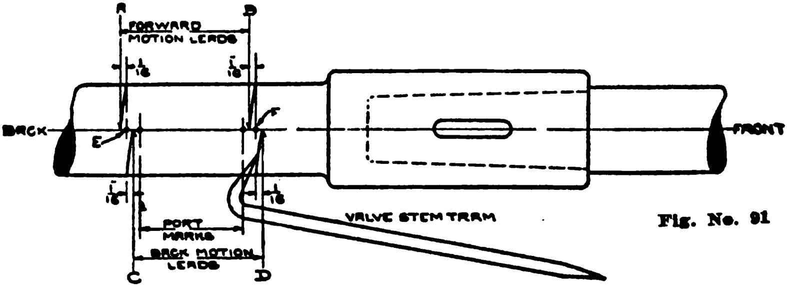


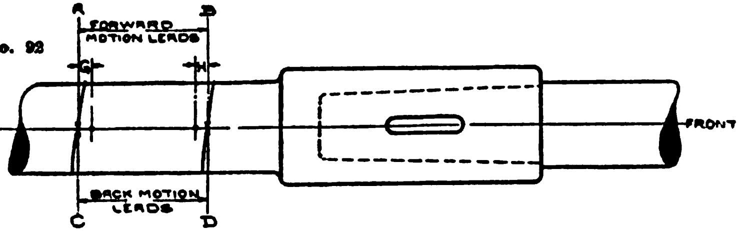
Fig. No. 91

Valve Rod and Eccentric Rod Adjustments. The errors in these rods manifest themselves by distorting the entire steam distribution. The most convenient method, however, of calculating these errors is through their effect on the lead. The methods herein described have been found generally satisfactory, although there are several other good ways.

Place the reverse lever in full forward position. Rotate the wheels forward and catch successively each of the four dead centres and scribe the valve stem to show the lead.

Place the reverse lever in full backward position.

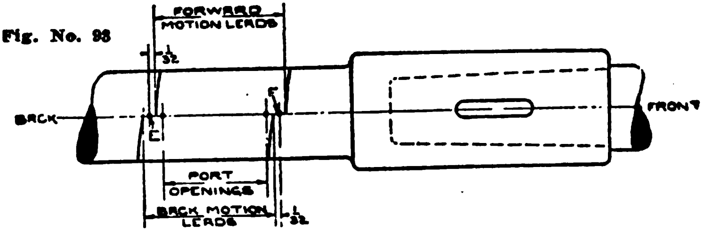
Fig. No. 92



Rotate the wheels backward and scribe the valve stem to show the lead at each dead centre.

The inside admission gear is direct in the forward motion and indirect in the back motion and the ratio of the gear is 4 to 1, therefore the valve will move forward 1/16″ if the eccentric rod is lengthened ¼″ **with the lever in the extreme forward motion and the engine on dead centre.** If the lever is in the extreme back motion the valve will move back 1/16″ when the rod is lengthened ¼″. Having taken the port marks with your standard valve stem tram, take the lead openings in both motions as shown by Fig. 91, which shows eccentric rod ¼″ too long for inside admission.

Fig. No. 93



If you shorten the rod ¼″ and take the lead points again the valve will be shifted back in the forward motion until lead line "A" is at "E," and lead line "B" is at "F," and in the back motion the valve will be shifted ahead until the lead line "C" will be at "E" and lead line "D" will be at "F," which will make the condition as shown at Fig. 93.

After obtaining leads as shown by Fig. 93, the length of the valve rod should be adjusted, making "G" and "H" equal. After the setter has had some experience the valve rod and eccentric rod alterations can be made after one revolution of the wheels. Referring back to the paragraph on Eccentric Crank Setting, which can be checked from the stem (see Fig. 92), on which the distance between "A" and "B" on the horizontal line of the stem is equal to "C" and "D," this will always be the case when crank setting is correct, whether the eccentric rod shows long or short.

If the eccentric rod is 1/8" too short and the crank setting correct, the full gear lead lines will come as shown by Fig. 93.

After lengthening the rod 1/8" you will have the condition shown by Fig. 92.

The foregoing includes inside admissions only and alterations in the eccentric rod length should be opposite for outside admission valves.

The Baker Gear gets its motion from two points: the eccentric crank and the crosshead. The eccentric crank moves the radius bar and the action the radius bar has on the valve is controlled by the reverse yoke. The radius bar and the yoke take the place of the link and block of a link motion.

The crosshead moves the valve the amount of the lap and lead each way. This makes the lead constant and independent of the cut off.

Having a constant lead, the valve should show lead opening in all cut offs when engine is on either dead centre.

With the Baker Gear the eccentric crank always follows the crank pin. It stands the same for both inside and outside admission.

If the eccentric rod is not the correct length, you can tell it by the following rule: If cut offs are long on front end in forward motion and long on the back end in backward motion, the rod is too long.

If the cut offs come just the opposite of the foregoing, then the rod is too short.

Valve rod: The valve rod change is always in the direction to correct the greatest error. Eccentric rod: On inside admission gears the change in the eccentric rod is always in the direction the valve should move to correct the forward motion. On outside admission gears this change is just the opposite.

The valve setter by experience will be able to calculate and make the necessary changes in the valve rod and eccentric rod at the same time. The valve rod adjustment should always be determined first.

When the changes in the valve rod and eccentric rod as outlined above have been made, the lead should be measured on the four dead centres in each direction to check the work.

At the time of checking the leads the extreme travel points of the main crosshead should be marked on the guide with a scriber, as these lines represent the extreme travel of the crosshead and are for use later when measuring the Cut off, Release, and Compression.

Adjusting Full Gear Valve Travels. The full gear valve travels can be corrected and equalized between the two sides of the engine while checking the lead, as above. The quadrant or power reverse gear should be laid out for extreme travel points. When lugs to limit the travel of the reverse yoke are provided on the valve gear frames, these should be chipped to correct height. The reverse yokes should touch these lugs when the maximum specified valve travel is being produced but—the power reverse gear should be adjusted so the yokes will clear the lugs ¼". The lugs are for the purpose of providing a positive stop against creeping. In the case of engines equipped with a reverse lever or screw reverse, the valve travel can be limited by the reversing mechanism and the lugs disregarded.

The full gear positions of the reverse yoke for inside admission should not be less than 5⅞" from the bell crank pivot in the forward motion, and not greater than 20¼" in the back. With outside admission gear, this dimension for the forward motion positions of reverse yoke should not exceed 20¼" and not more than 6¼" in the back motion.

These figures should be checked after the boiler has been fired up to correct errors caused by boiler expansion.

Checking Cut off. After the leads have been equalized the Cut off should be measured in at least one position of the reverse lever, usually running position in forward motion. On passenger engines it is customary to measure it at 25% cut off position and on freight engines 33%. If the cut off does not vary more than ¾" the valve setting may be considered correct. Occasionally slight additional adjustment may be required to keep within this limit.

TRAILING

Valve Setting without taking the dead centres is commonly called "Trailing" because it is usually accomplished by moving the engine with its own steam or with another engine. Only the eccentric rods, valve rods, or reach rods should be altered in these circumstances.

Object to be Accomplished. It is of course impossible to accurately measure the lead without taking the dead centres—therefore the object sought in this method of valve setting is to make the valves open the steam ports an equal amount on front and back ends on both sides of the engine and in both motions.

When Correct. Experience has shown that if the port openings at about 40% cut off are made equal, the engine may, for this type of valve setting, be considered correct.

Method Used. The reverse yoke should be placed at about 10½" from centre of bell crank (frame bearing pin) to centre of radius bar bearing in reverse yoke for forward motion and 15¾" for the same dimension in back motion; this will suit practically every case (for inside admission). For outside admission, reverse the figures. Another way is to set the reverse lever to produce an average port opening of about 7/16". The engine should be moved one complete turn in each direction and the valve stem scribed to show the extreme movement of the valve. Particular care must be taken to see that the valve travel is the same on each side of the locomotive and that the maximum travel of valve is correct. Do not mark the valve stem until all the slack has been absorbed and the reverse lever is in the correct position.

Valve Rod and Eccentric Rod Changes. The manner of calculating the changes is the same as when the lead dimensions are available; and, because of the now different positions of the valve gear parts, when the readings are obtained, the ratio of the eccentric rod change to the valve movement is the same (4 to 1) provided the reverse yokes are set as described in the foregoing paragraphs.

Rules. The port opening should be squared at about 40% cut off and not in full gear positions.

Make valve rod change first; always in direction to correct greatest error.

Eccentric rod change in the direction valve should move to correct the forward motion on inside admission gears; and on outside admission gears this change is just the opposite.

It is recommended that the valve setter keep a record of each engine adjusted in this manner, showing the condition of the engine as he found it, the changes made and the condition of the engine as he left it. This will be of assistance in correcting any errors in calculation.

Reach Rods. If too great a difference is found between the travel of the valve on one side of the engine as compared to the other side, the gear reach rod may be lengthened on the side of short travel, to make the travel equal.

ACCIDENTS

The handling of The Baker Locomotive Valve Gear in case of accident is of utmost interest to all engineers, but should not present any special difficulties.

It is difficult to lay down rules to cover every case that might arise. It is possible, however, to consider some of the more usual or most possible accidents; and determine the best and quickest course to follow in such cases.

The accidents to be considered may be divided into two general classes; those in which it is not necessary and those in which it is necessary to cover the ports.

The first case of accidents are those in which it is not necessary to take down main rod and cover the ports, and are placed under the heading of:

MAIN ROD UP, VALVE NOT BLOCKED

If eccentric crank, eccentric rod, connecting rod, radius bar, horizontal arm of bell crank or reverse yoke below reach rod connection break.

Take down eccentric rod, block bell crank (if it is of the two-arm type plumb it in a vertical position; if of single arm type, make lower bearing 1¼ inches ahead of upper bearing); when bell crank is thus secured, care must be taken not to come to a stop with the main pin on the disabled side of either quarter. In such an event, the combination lever will be in a perpendicular position, or approximately so; as the main pin on the opposite side would be on dead centre, it would thus be impossible to start the locomotive. When any of the above accidents occur, the valve on the disabled side then receives a motion from the combination lever. Its travel will be equal to twice the total amount of the lap plus the lead. This gives a port opening equal to the amount of lead, consequently the main rod may be left up, as the cylinder will be lubricated. Furthermore, though the cut off on the disabled side will be very short, the steam that is admitted will do a certain amount of work; and the engine can be reversed.

If gear reach rod, reverse arms or reverse yoke at reach rod connection break.

Remove broken parts, block disabled side in desired position and proceed with train (it being understood that engine should not be reversed without first changing the blocking on the disabled side).

If main reach rod, reverse shaft bearing or reverse arm to which main reach rod is connected fail.

Block both reverse yokes at desired cut off controlling speed with throttle.

The second class of accidents; those in which it is necessary to cover the ports. This class is subdivided into two other classes; first, cases where it is necessary to take down the main rod; second, those in which the main rod is in condition to run. Taking up these two kinds of accidents in their order.

MAIN ROD DOWN, VALVE BLOCKED

If the main rod, main crosshead, guides or piston is damaged.

Take down main rod and valve rod, leaving rest of gear intact. (If main rod is of the solid rear end type, making is necessary to remove eccentric rod and crank, valve rod may be left up.) Place valve over ports. It can readily be determined if valve is properly placed by applying brakes to engine, opening cylinder cocks and admitting a small volume of steam. If steam does not blow through, secure valve by means of set screw provided for this purpose, which will be found on valve stem guide, valve stem crosshead or rocker boxes. If no set screw is provided, a valve stem clamp is usually included in the tool equipment. Clamp or block main crosshead at front or back end of guides as per Railroad Company's instructions. With the valve motion disconnected in this way, the reverse lever is free to operate the other side; and locomotive can be run in on one cylinder, by working engine at long cut off.

If crosshead wrist pin should break and combination lever is driven from it.

Do the same as when main rod, main crosshead, guides or piston is damaged, except take down union link and wire bottom end of combination lever to some convenient place to keep it from swinging.

MAIN ROD UP, VALVE BLOCKED

When main rod, main crosshead, guides and piston on the damaged side are in condition to run, the main rod may be left up, provided there are relief or vacuum valves in the cylinder heads, these may be removed so that cylinder may be lubricated and excessive compression avoided.

If vertical arm of bell crank should break and combination lever is suspended from it.

Take down combination lever, union link and valve rod.

If vertical arm of bell crank should break with combination lever suspended from valve stem crosshead or if cylinder head be broken or blown out.

Take down valve rod.

If union link, crosshead arm or combination lever fail.

Take down valve rod, fasten lower end of combination lever ahead to clear main crosshead on forward stroke. Of course such of the broken parts as would in any way interfere with the running of the locomotive would have to be removed.

THE SOUTHERN VALVE GEAR

While this gear is a radical departure from all previous outside valve gears, it is a gear that can be adapted to any class of locomotive, either inside or outside admission.

The Southern Valve Gear has eliminated many objectional features found in other outside gears. It is very simple, compact, and contains but few wearing points; the cross head connections have been dispensed with, and the weight has been correspondingly reduced.

The Southern Valve Gear will give full port opening with 2½ inches piston travel, the lap and lead as well as total travel of valve being taken from the eccentric crank, having few angularities and wearing parts to pass through before reaching the valves. With other radial types of gears taking lap and lead movement from cross head by means of combination levers the cross head travels from 4½ to 5 inches before full port opening is obtained, lap and lead movement being transferred to valves from slowest moving point of piston stroke. This robs the valve of its speed at the point of the stroke where quick movement is needed.

When the valves are properly adjusted, the gear is so designed as to eliminate the necessity of any adjustment while the engine is in service.

Transferring from a rotary to a reciprocating motion is accomplished by direct movements and on straight lines, doing away with strains and distortions found in other valve gears, in common use today; the links are horizontal and stationary, doing away entirely with the wear at this point, the block only moves in the link when the reverse lever is moved to adjust the cut off, or reverse the gear. The links being stationary does away with the slip in the link block, found in some outside gears. There are but eight possible points of wear to the side, or a total of sixteen wearing points per locomotive.

The different parts are balanced to reduce the wear on the pins and bushings to a minimum. All bearings, pins and bushings of the Southern Valve Gear are of such size as to insure long usage with very little wear. The forward end of the Eccentric Rod is supported by a Bell Crank Hanger, having at its top

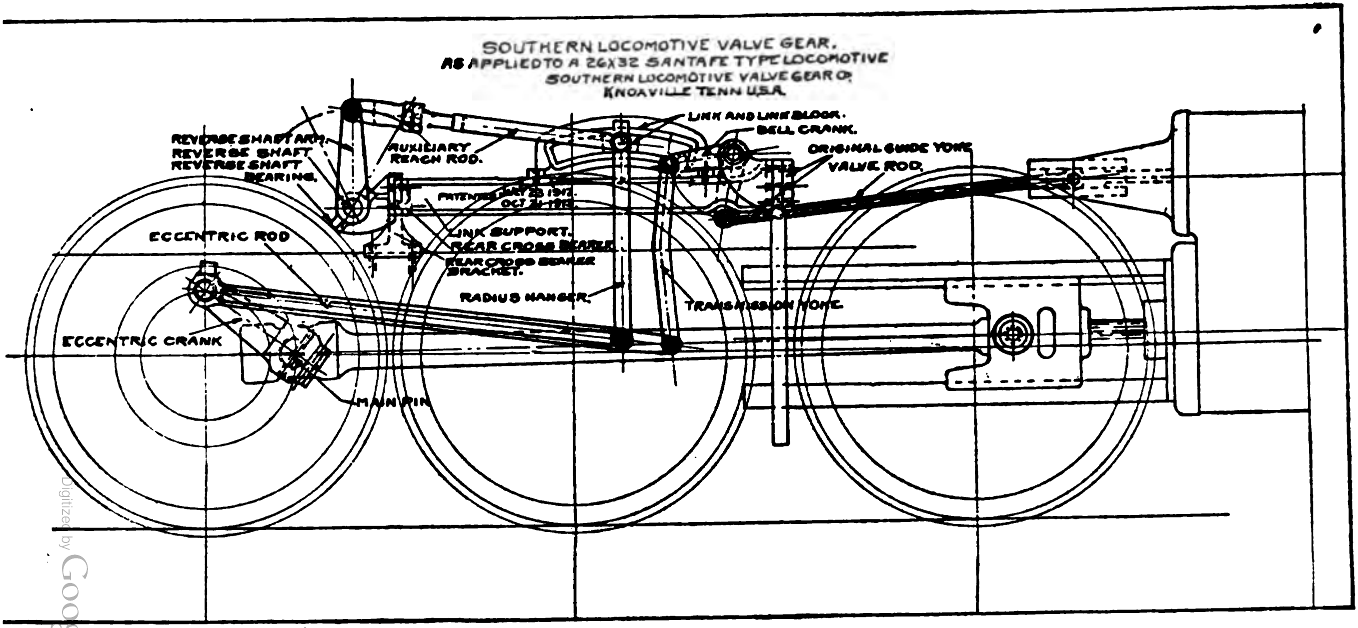

SOUTHERN LOCOMOTIVE VALVE GEAR.
AS APPLIED TO A 26X32 SANTA FE TYPE LOCOMOTIVE
SOUTHERN LOCOMOTIVE VALVE GEAR CO.
KNOXVILLE TENN U.S.A.
REVERSE SHAFT ARM.
REVERSE SHAFT
REVERSE SHAFT BEARING.
AUXILIARY REACH ROD.
LINK AND LINK BLOCK.
BELL CRANK.
ORIGINAL GUIDE YOKE
VALVE ROD.
PATENTED MAY 29 1917.
OCT 1917.
LINK SUPPORT.
REAR CROSS BEARER
REAR CROSS BEARER BRACKET.
RADIUS HANGER.
TRANSMISSION YOKE.
ECCENTRIC ROD
ECCENTRIC CRANK
MAIN PIN

Fig. No. 95

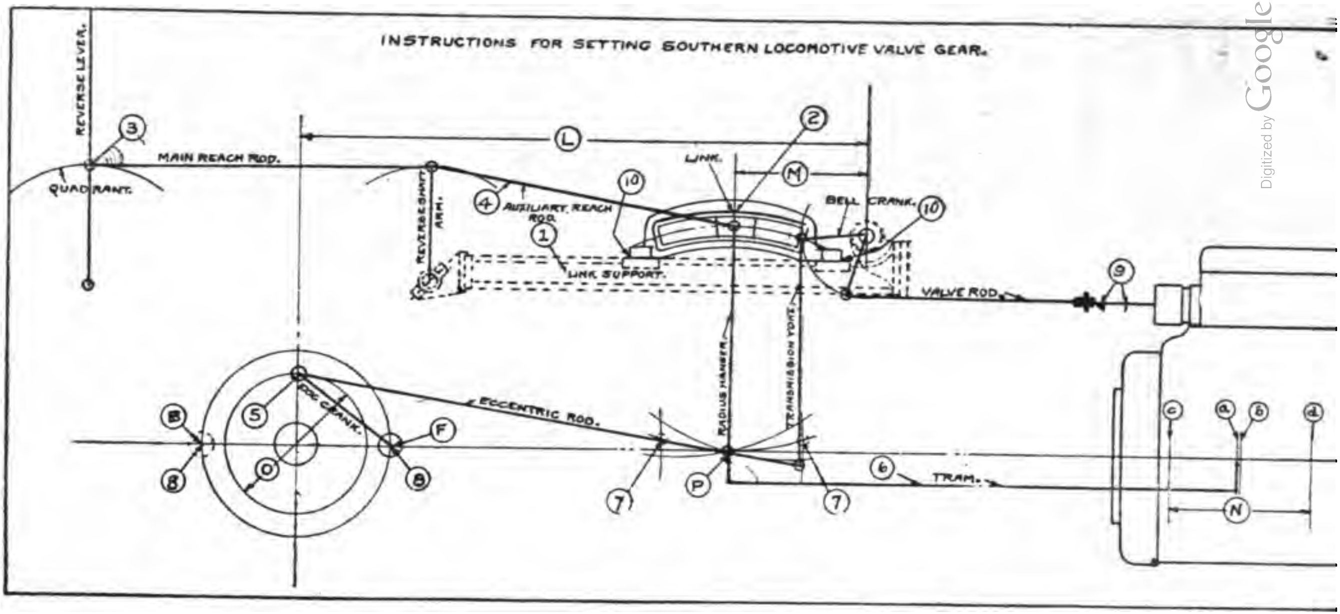

INSTRUCTIONS FOR SETTING SOUTHERN LOCOMOTIVE VALVE GEAR.
REVERSE LEVER.
3
MAIN REACH ROD.
QUADRANT.
L
2
LINK.
M
REVERSE SHAFT ARM.
4
AUXILIARY REACH ROD.
10
1
LINK SUPPORT.
BELL CRANK.
10
9
VALVE ROD.
RADIUS HANGER.
TRANSMISSION YOKE.
ECCENTRIC ROD.
ECC. CRANK.
5
B
8
O
F
8
7
P
7
6
TRAM.
c
a
b
d
N

Fig. No. 96

two bearings spaced widely apart, thus preventing any side thrust on the eccentric rod.

The Southern Gear is designed to eliminate all stress and strains on reverse lever and reach rod connections, the reverse lever is easily handled while working full head of steam. This feature appeals strongly to the engineers and enables them to adjust the cut off without fear of the lever getting away from them.

SETTING AND ADJUSTING SOUTHERN VALVE GEAR

Set the link supports so that dimensions conform to figures on erecting card. Then connect the gear as shown on the erecting card.

Set the Links so that dimension (M) conforms to erecting card. (See Fig. 96.)

Set Reverse Lever in centre of quadrant, adjust the main Reach rod, so that Reverse Shaft Arms will stand in vertical position.

Adjust Auxiliary Reach Rods so that Link Block will be in centre of link when the reverse lever is in centre of quadrant.

Set Eccentric Crank for inside admission to follow Main Crank Pin, and for outside admission to Lead Main Crank Pin, at a distance from centre of Main Axle to centre of Eccentric Crank Pin to conform to erecting card.

Find dead centres in usual way. With the engine on front dead centre (F), tram from centre of Radius Hanger Pin (P) to any stationary point on Cylinder Casing or Guide Yoke, and scribe arc (a) as shown.

Then place engine on back dead centre (B) and again scribe arc (b) from centre (P). If arcs (a and b) fall line and line, the eccentric crank setting is correct. If they do not, then move eccentric crank to or from centre until they do.

Then revolve wheel or move engine one full turn, and tram in same centre (P) and scribe arcs (c and d). If full travel (N) is within 1-16″ of eccentric crank circle (O) shown on erecting card they are correct. If there is a difference of as much as ⅛″ in full travel of eccentric crank pin, lengthen the eccentric crank having the least full travel one-fourth of the difference, and reset eccentric cranks as per paragraphs 5 and 6.

Place engine on front and back dead centres (F and B) and move reverse lever entire sweep of quadrant. If valve moves in same direction as link block, move link ahead; if opposite direction move the link back until still valve is found.

Then try lead and adjust the valve rods for cut off in full gear, and at approximately 9″ working cut off, if the engine cuts off heavier in front end of cylinder, on inside admission, shorten the valve rod; if heavier in back end of cylinder, lengthen the valve rod. Outside admission require opposite changes.

Raising or lowering the links by means of liners has the same effect as lengthening or shortening the valve rods.

If one side shows a greater total cut off then the other, lengthen or shorten the auxiliary reach rod, whichever is most convenient, as lengthening the aux-

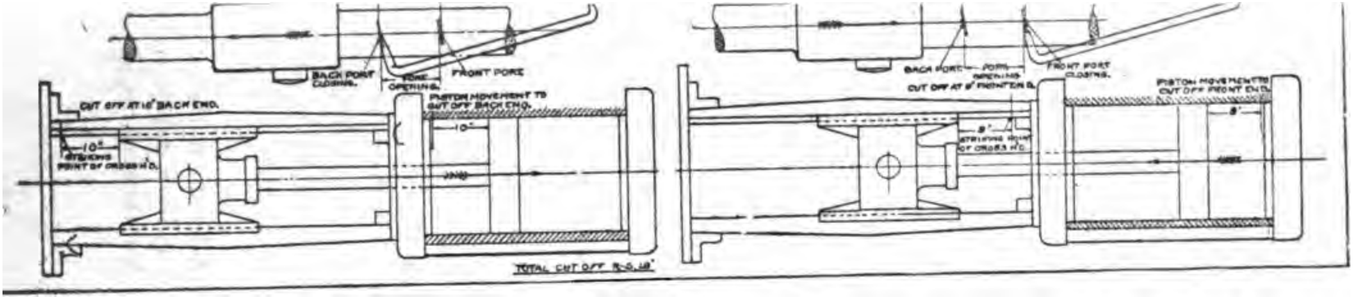


Fig. No. 97

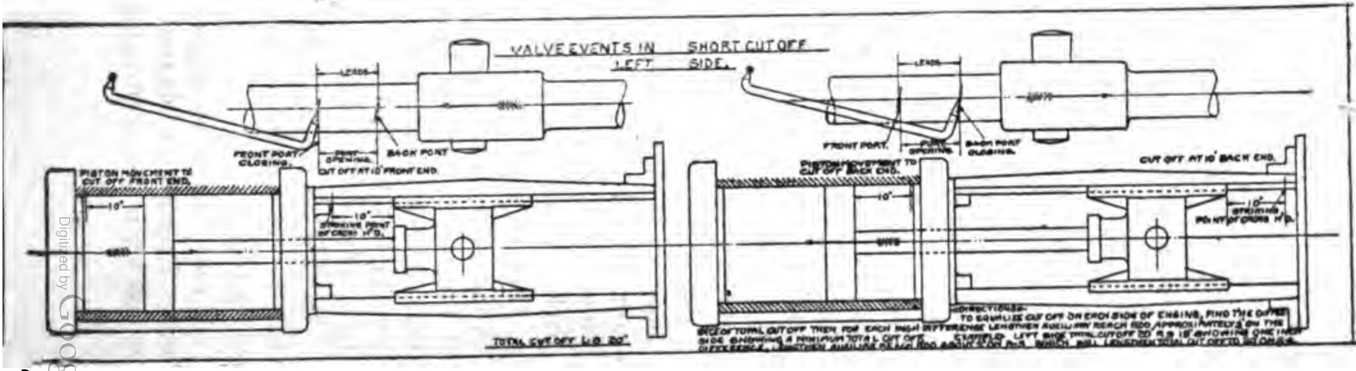

VALVE EVENTS IN SHORT CUT OFF
LEFT SIDE.
LEADS
FRONT PORT CLOSING.
PORT OPENING.
BACK PORT
CUT OFF AT 10" FRONT END.
PISTON MOVEMENT TO CUT OFF FRONT END.
10"
10"
STRIKING POINT OF CROSS H'D.
TOTAL CUT OFF L.S. 20"
LEADS
FRONT PORT.
PORT OPENING.
BACK PORT CLOSING.
PISTON MOVEMENT TO CUT OFF BACK END.
CUT OFF AT 10" BACK END.
10"
10"
STRIKING POINT OF CROSS H'D.
DIRECTIONS—
TO EQUALIZE CUT OFF ON EACH SIDE OF ENGINE, FIND THE DIFFERENCE OF TOTAL CUT OFF THEN FOR EACH INCH DIFFERENCE LENGTHEN AUXILIARY REACH ROD APPROXIMATELY ⅜ ON THE SIDE SHOWING A MINIMUM TOTAL CUT OFF. EXAMPLE: LEFT SIDE TOTAL CUTOFF 20 R.S. 18 SHOWING ONE INCH DIFFERENCE, LENGTHEN AUXILIARY REACH ROD ABOUT ⅜ ON R.S. WHICH WILL LENGTHEN TOTAL CUT OFF TO [illegible]

Fig. No. 98

iliary reach rod increases valve travel and total cut off, while shortening auxiliary reach rod decreases the valve travel and total cut off.

When setting valves with engines on jacks, have the main wheels placed ½ inch under actual running height. For instance, if blue print running height is 18 inches when engine is on rail, set the main wheels at 17½ inches running height on jacks.

BREAKDOWNS ON SOUTHERN VALVE GEAR

1st. If the Eccentric Crank or Eccentric Rod fails.
Disconnect the eccentric rod from crank, radius hanger, and transmission yoke, tie up the hanger and yoke, clamp valve central position and proceed.

2d. If Radius Hanger fails.
Disconnect the hanger from rod, and take down eccentric rod, clamp valve in central position and proceed.

3d. If Transmission Yoke fails.
Disconnect from eccentric rod and clamp valve in central position and proceed.

4th. If Horizontal Arm of Bell Crank fails.
Disconnect the yoke from eccentric rod, tie up to clear, clamp valve in central position and proceed.

5th. If Vertical Arm to Bell Crank fails.
Clamp valve in central position and proceed. Take the broken arm down if necessary.

6th. If one Auxiliary Reach Rod or Reverse Shaft Arm fails.

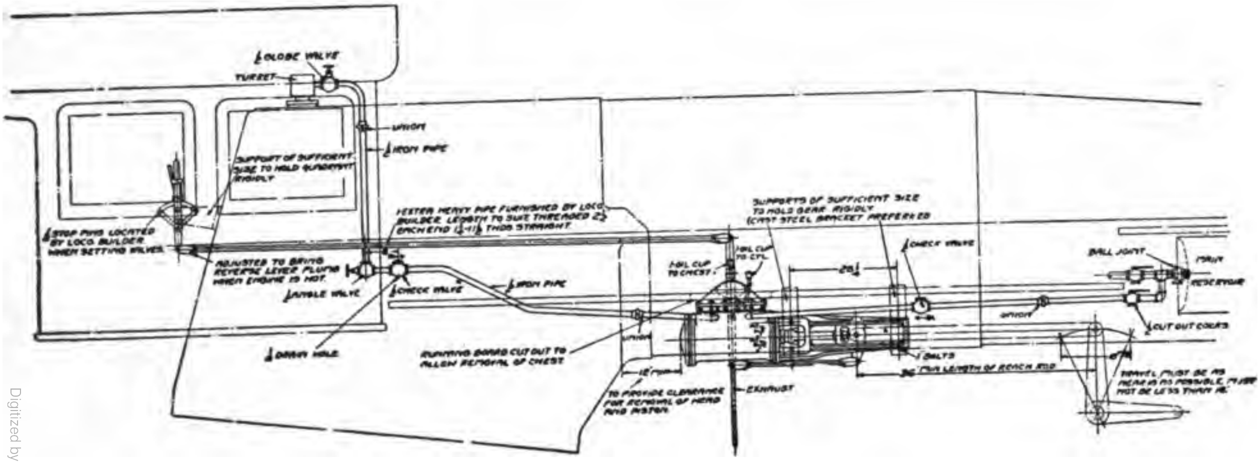

½ GLOBE VALVE
TURRET
UNION
½ IRON PIPE
SUPPORT OF SUFFICIENT SIZE TO HOLD QUADRANT RIGIDLY
EXTRA HEAVY PIPE FURNISHED BY LOCO. BUILDER. LENGTH TO SUIT THREADED 2½ EACH END (2½-11½ THDS STRAIGHT
½ STOP PINS LOCATED BY LOCO. BUILDER WHEN SETTING VALVES.
ADJUSTED TO BRING REVERSE LEVER PLUMB WHEN ENGINE IS HOT.
½ ANGLE VALVE
½ CHECK VALVE
½ IRON PIPE
½ DRAIN HOLE
RUNNING BOARD CUT OUT TO ALLOW REMOVAL OF CHEST
UNION
12" MIN
TO PROVIDE CLEARANCE FOR REMOVAL OF HEAD AND PISTON
OIL CUP TO CHEST.
OIL CUP TO CYL.
EXHAUST
SUPPORTS OF SUFFICIENT SIZE TO HOLD GEAR RIGIDLY (CAST STEEL BRACKET PREFERRED
20¼
½ CHECK VALVE
¾ BOLTS
36" MIN LENGTH OF REACH ROD
UNION
BALL JOINT
MAIN RESERVOIR
½ CUT OUT COCKS
TRAVEL MUST BE AS NEAR 6" AS POSSIBLE. MUST NOT BE LESS THAN 5"

Fig. No. 80

Block both link blocks in same position of links, and in such a position as to give port opening enough to start train.

7th. If Main Reach Rod, or Middle arm of Reverse Shaft fails. If both Auxiliary Reach Rods fail. Block link blocks in such position as to give port opening enough to start train.

Diagram 95 shows names of all parts.

RAGONNET POWER REVERSE GEAR

With heavy trains and fast schedules, correct cut off adjustment is of great importance.

Ragonnet invites the right cut off because the work of moving the heavy valve gear is done by power, controlled by a small hand lever.

OPERATION OF GEAR

Movement of the cab reverse lever is transmitted to the slide valve through the reach rod, the combination lever and rocker. This movement opens the port at one end of the cylinder to air pressure and the other port to exhaust. The piston will then move until the cut off corresponds to the position indicated by the reverse lever, when the combination lever again places the rocker arm in a vertical position closing the cylinder ports. Careful proportioning of the combination lever and the valve lap renders the gear sensitive to the slightest movement.

Between the ends of the valve and the valve chest there is only sufficient clearance to allow the valve to uncover the cylinder ports. The reverse lever can be thrown only this distance until the gear moves a corresponding amount. The point of cut off will therefore correspond to the position indicated by the reverse lever even without reservoir pressure.

While this construction in no way limits the speed of the gear it prevents undue stresses from moving the lever more rapidly than the gear can respond. It also prevents movement of the lever while there is no pressure in the cylinder. This renders impossible a false indication of the position of the gear.

Should there be any tendency for the gear to move, the slide valve will be displaced admitting air to the cylinder and returning the crosshead to the exact position shown by reverse lever.

The air cylinder in addition to fixing the cut off also maintains it. It also provides an air cushion which absorbs the valve shocks, reducing wear on the valve motion.

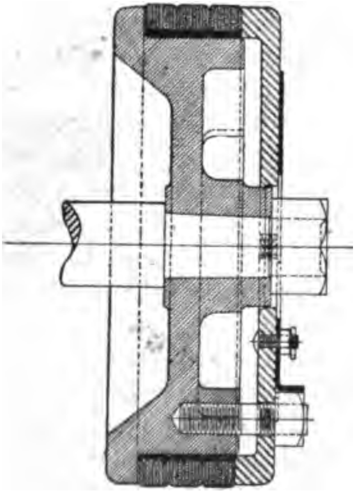


Fig. No. 100

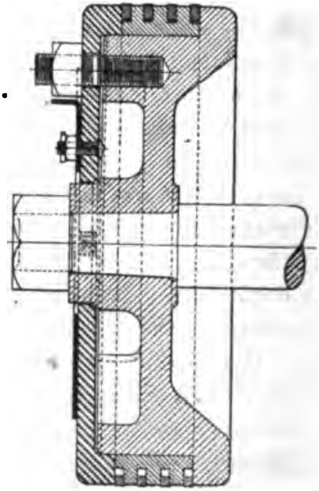


Fig. No. 101

"RAGONAY" CYLINDER PACKING

"Ragonay" packing (Fig. 100) has been developed especially for Ragonnet Power Reverse Gear and should be used to insure best results.

When applying new packing the follower should be drawn up tight enough to expand the packing in the cylinder, care being taken not to cause undue friction.

Metallic Packing (Fig. 101) is made to fit the same space as the "Ragonay" packing by the use of a special bull ring. "Ragonay" packing may be substituted at any time if desired.

CARE OF GEAR

Gears should be oiled and oil cups filled with engine oil every trip.

Piston, Fig. 100, should be packed with three rings of "Ragonay" Packing.

After examining or renewing cylinder packing, piston and cylinder should be greased with soft grease or cylinder oil.

Piston packing should be kept tightly set up but not so as to cause undue friction. An air blow at this point may cause gear to float back and forth.

All lost motion should be kept out of reach rod pin connections.

Operate gear by air pressure—in emergency only should steam be used. The cut out cock must then be closed as soon as convenient to keep water out of the reservoir.

For best results, the Power Reverse Gear should be overhauled each time the locomotive receives general repairs.

LOCOMOTIVE RUNNING

Care and Operation of Locomotive Lubricators

The hydrostatic system of lubrication for oiling the valves and cylinders of locomotives is based upon the principle of hydrostatic displacement, utilizing the pressure due to a head of water, together with the difference in the specific gravities of oil and water, to force the oil from the oil reservoir into the tallow pipes. The following will explain the principle:

THE PRINCIPLE OF THE HYDROSTATIC LUBRICATOR

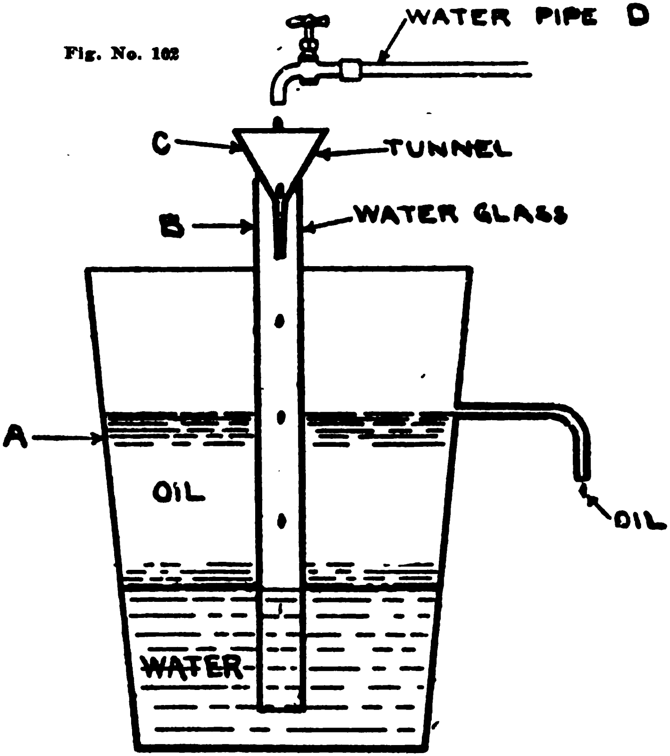
By observing Figs. 102, 103, 104, it will be seen there are three developments or approaches to the present hydrostatic lubricator.

Let us look at Fig. 102. Here we have an ordinary water pail in which we will place a gallon of oil. Place the water glass-B. into the oil, leaving about one inch space from the bottom of the pail to the water glass. Place the tunnel-C into the position shown and let water pass through the glass to the bottom of the pail-A.

Since oil is lighter than water, it will float on top and as we increase the amount of water the higher the oil will rise until it overflows at the elbow attached to the pail as shown.

No water will discharge through the elbow until all the oil is out, because the water must first displace the oil, and before taking up a description of Fig. 103, let us see how the oil flow is regulated. In this case, we must regulate the oil flow by the drip of the

Fig. No. 102



faucet attached to the pipe-D—in other words, a drop of water entering the water-glass will displace one drop of oil, and it will issue from the elbow accordingly, as the amount of water is introduced.

Next let us take up Fig. 103. Here we have placed a water tight cover on the pail, using the same water-glass made tight where it passes through the cover, and instead of using an elbow we will attach a valve

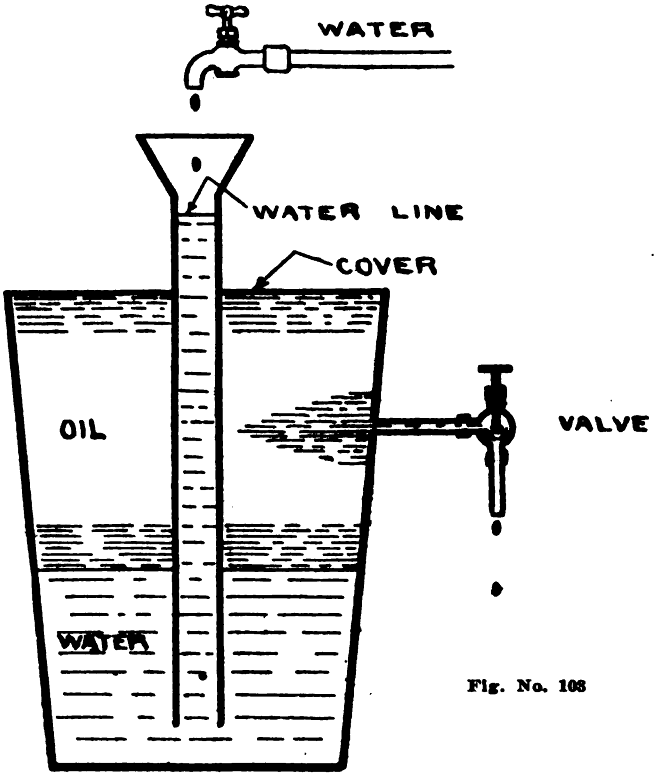


Fig. No. 108

to regulate the oil discharge. Let us now fill the pail with water sufficiently to force the oil up against the cover, and then continue to fill the water-glass until it is a few inches above the cover of the pail. By doing this we have put a slight pressure on the oil in the pail. Why? Because the column of water in the glass having a greater height has pressure and tends to force the oil out through the valve. The

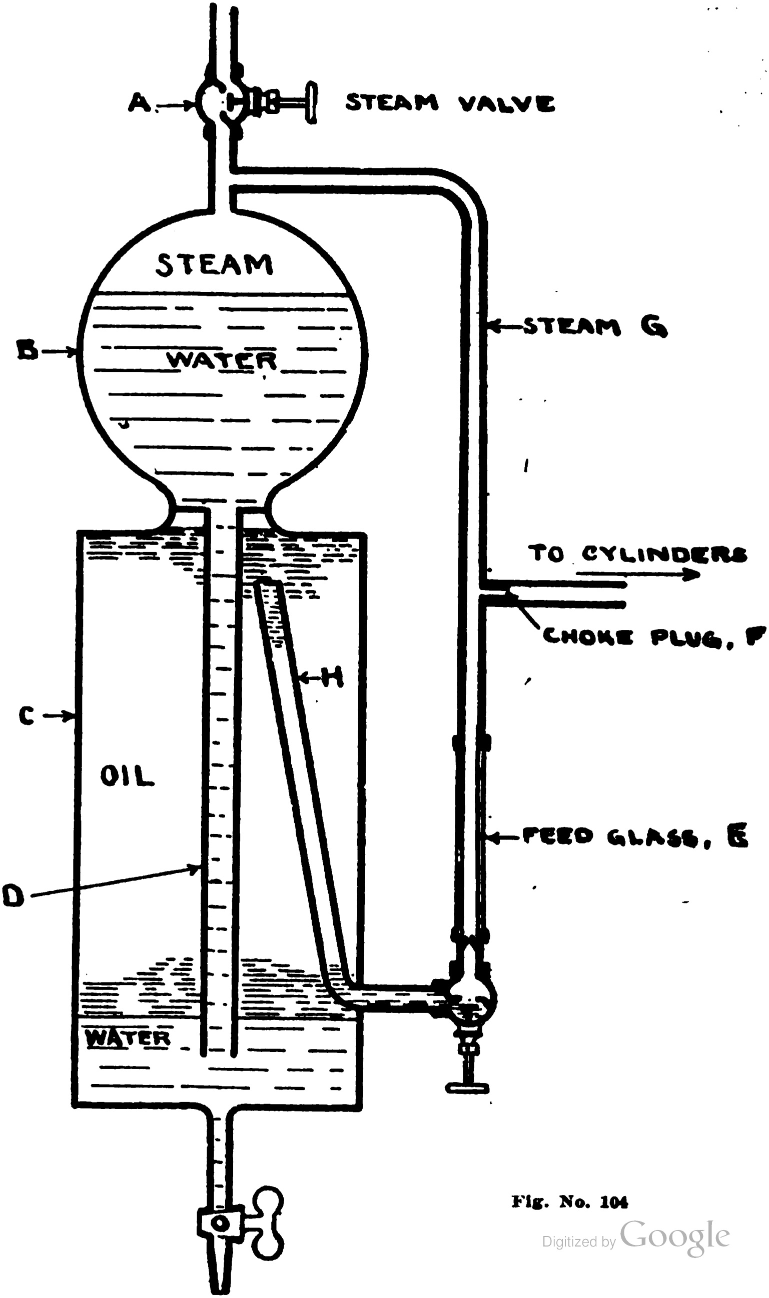

A.
STEAM VALVE
STEAM
B
WATER
STEAM G
TO CYLINDERS
CHOKE PLUG, F
H
C
OIL
FEED GLASS, E
D
WATER

Fig. No. 104

total pressure though very slight is the distance from oil valve to the top of the water in the glass.

Fig. 104 shows the old style sight feed lubricator. Here we use water from the condensing chamber or condensed steam, and a pipe attached to the top of the sight feed glass admitting steam and balancing the pressure on top of the feed glass. A choke plug will be seen in the figure for the purpose of forcing the oil out to the tallow pipe but not so large as to unbalance the pressure on top of the feed glass. The pressure on top of the feed glass must be kept constant since the operation of the lubricator must depend only on the head or height of water in the condensing chamber, as explained in the second example of the principle already described.

It was not until about 1884 that attempts were made to apply the hydrostatic displacement principle for oiling the valves and cylinders of locomotive engines. Considerations of convenience and accessibility made it desirable to take the steam supply directly from the boiler and connect the oil pipes to the top of the steam chest. This mode of connecting up the lubricator resulted in full boiler pressure prevailing at all times at the inlet end of the lubricator, while at the outlet end, the pressure was variable according to whether the engine was running under steam or with throttle closed, as when drifting on a down grade or running into a station.

This condition necessitated the use, and resulted in the invention of what is termed the "Equalizing Feature." This consists in a steam chamber located near the delivery end of the lubricator, which chamber is at all times subjected to direct boiler pressure, and from which the steam and oil are permitted to escape through a passage of such small size that the pressure at the outlet is maintained at practically that of the boiler. By this means the pressure at the outlet and inlet of the lubricator are balanced, or equalized, irrespective of the pressure in the steam chest and in the oil pipes.

When the boiler pressure of locomotives began to be increased, it was discovered that under certain conditions the lubricator did not deliver the oil into the steam chest or cylinder owing to the fact that the back pressure from the steam chest at the delivery end of the oil pipes was greater than the pressure exerted by the small volume of steam passing through the choke plugs at the receiving end.

Numerous steam chest attachments were introduced to assist the lubricator in delivering oil under adverse circumstances, consisting of automatic valves, which under variations of pressure in the steam chest vary the opening proportionately, increasing it for the delivery of steam and oil when the engine is working, and choking it when steam is shut off from the chest.

Changes in the conditions of locomotive practice, particularly in continually increasing boiler pressure, necessitated changes in the construction of lubricators to make their operation reliable and safe for enginemen. Glasses particularly received attention, as the tubular form became more and more unreliable and dangerous. A constructive change of vital importance consisted, therefore, in replacing the tubular sightfeed and gauge glasses by a new form of glass popularly known as "Bull's Eye."

These glasses have the form of a thick, round disc. They do not break, and even if they should crack, they do not fly around, but remain embedded in their casings, so that the enginemen are safeguarded against injuries which otherwise might result. The fact that these glasses are safe under high pressure permitted the elimination of parts otherwise necessary, making the lubricators simpler and more compact, reducing the number of parts and, therefore, the cost of maintenance.

NATHAN BULL'S EYE LUBRICATOR

Type "166 F-5"

In connection with locomotive engine lubrication it develops occasionally, particularly with the use of superheated steam, that under very severe conditions, the feed of the lubricator is retarded by the back pressure from cylinders or steam chests, and the engine, under those conditions, does not obtain sufficient lubrication. It is useful and desirable under such conditions to admit a supply of steam into the oil pipes, in addition to that ordinarily passing through the choke plugs, to assist the delivery of oil to the valves. This desirable purpose is accomplished in the Bull's Eye lubricator with "Booster" pipes, type 166 F-5. (See Fig. 105.)

As may be observed from the illustration, pipes No. 40 lead from a suitable point at the top of the condenser into the oil pipes to the steam chest. These pipes connect with oil pipes ahead of the choke plugs. Steam admission to these pipes is controlled by the valve No. 38 which, when open, admits steam for the operation of the lubricator as well as supplying the Booster pipes and when this valve is closed, steam is shut off the lubricator altogether.

The valve 38 should be kept open at all times while the engine is in service. Any type of Bull's Eye Lubricator may be provided with "Booster" pipes as the Booster attachment is an external one and in no way affects the standard construction or the general operation of the lubricator as described.

Bull's Eye Lubricators with "Booster" pipes are not provided with hand oilers.

The type 166 F-5 lubricator is made with 3 to 7 feeds and capacities of 3 to 7 pints.

The opinion prevails with a great many men interested in the lubrication of locomotive engines that the air pump feed should always remain open while the engine is in service, even at such times as the steam chest feeds may be cut out for the sake of economy as when a train for some reason is compelled to remain for a considerable time on a siding. In such cases the air pump continues working to counteract leaks in long train pipes, and requires lubrication.

The construction of the lubricator Type 166 F-5 provides for these conditions. It is provided with an oil cut-out valve, part 56, which is an ordinary screw valve. In lubricators with uneven number of feeds this valve, when closed, cuts out all feeds except the centre one which usually is the feed leading to the air pump and the operation of which is not affected by the cut-out valve. In lubricators with even number of feeds, the oil cut-out valve, when closed, cuts out all feeds except the two innermost ones, which may lead to two air pumps or to an air pump and stoker.

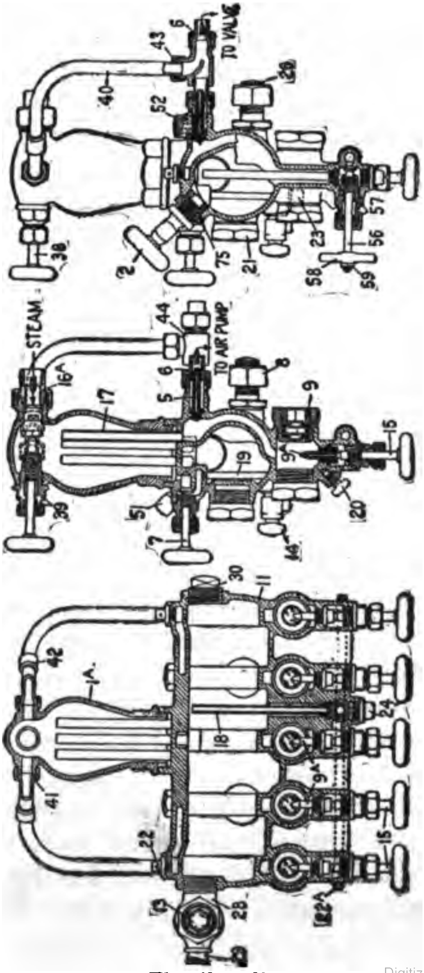


Fig. No. 105

To open the cut-out valve, turn handle 58 to the left. To close it, turn handle 58 to the right as in the case of any common screw valve. At no time should the steam valve be closed while the lubricator is in use.

BULL'S EYE LUBRICATOR
Type "166 F-5"
With "Booster" Pipes and Oil Cut-out Valve

No. of Part	Name of Part
1.A	Condenser
2.	Filling Plug
5.	Reducing Plug
6.	Delivery Nut and Tailpiece
7.	Water Valve
8.	Stud Nut
9.	Sightfeed Glass and Casing
9A.	Feed Nozzle
11.	Body
13.	Gauge Glass and Casing
14.	Waste Cock
15.	Regulating Valve
16.A	Top Connection
17.	Equalizing Pipes
18.	Oil Pipe
19.	Water Pipe
20.	Sight-feed Drain Valve
22.	Body Plug
22A.	Body Plug (small)
23.	Body Plug (large)
24.	Oil Pipe Plug
26.	Support Stud.

28. Gauge Glass Bracket
29. Cleaning Plug (Gauge Glass)
30. Gauge Glass Cap
38. Steam Valve Spindle
39. Steam Valve Bonnet and Nut
40. Booster Pipe
41. Elbow Connection for booster pipe
42. Connecting Nipple for booster pipe
43. Packing Nut for booster pipe.
44. T—Connection for booster pipe
51. Plug for Filling Hole
52. Cap
56. Spindle Oil cut-out valve
57. Bonnet and Nut Oil cut-out valve
58. Handle Oil cut-out valve
59. Handle Nut Oil cut-out valve
75. Removable Seat for Filling Plug

DETROIT BULLSEYE LOCOMOTIVE LUBRICATORS

Oil Reservoir with Expansion Chamber

Oil heated to the temperature of steam at two hundred pounds pressure will expand about one-fifth in volume. While it is true that in common practice the oil in the reservoir of a lubricator is never heated to this degree, nevertheless, when the lubricator is not in operation, considerable expansion will take place, due to heating the oil remaining inactive in the reservoir. Unless provision is made for this expansion, the reservoir is subjected to excessive pressure. The expansion chamber in the top of Detroit Lubricators is designed to take care of any expansion taking

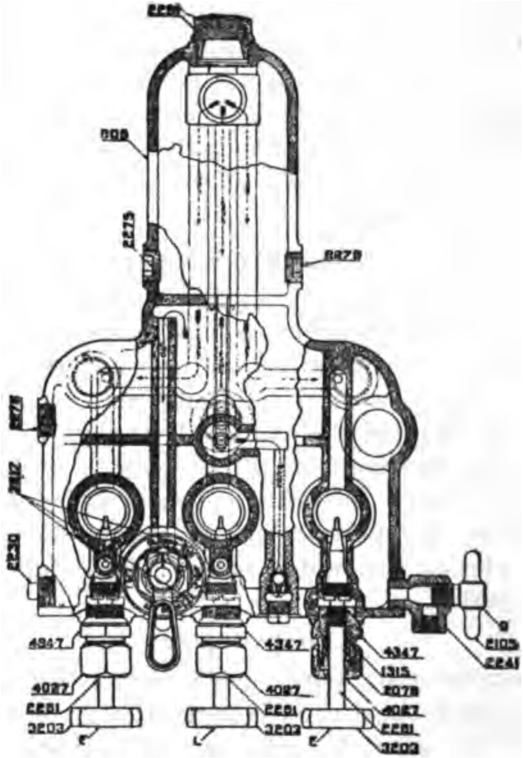


Fig. No. 106

place within the reservoir, thereby enabling the operator to fill the reservoir to its capacity without fear of resultant damage.

Condenser

Practically, the hydrostatic column which operates the lubricator is measured from the level of the discharge to the tallow pipe to the top of the equalizing tube. As the height of this column is influenced by the height of the condenser, the latter is important. The large capacity of the condenser in Detroit Lubricators is also of importance, in that it furnishes an abundant reserve supply of condensation, so that even an excessive amount can be withdrawn from the condenser without materially affecting the height of the hydrostatic column.

Water Check Valve

The brass ball check, at the bottom of the water passage, is an emergency feature designed to prevent syphoning or equalization of pressure through the water passage when by mistake the operator has failed to shut off the water valve before cutting off the boiler pressure from the condenser. It should be considered as a safeguard only and is not intended to relieve the operator from the responsibility of always closing the water valve before shutting the steam valve.

Steam Supply

Repeated tests have demonstrated that a large steam supply pipe is an important factor in the successful operation of any locomotive lubricator. With the sudden and extreme changes of pressure which occur in a locomotive steam chest, it is essential to the steady working of a lubricator that the volume of steam admitted through the boiler connection shall be of sufficient volume to provide not only ample condensation to displace the oil required, but, in addition, to maintain boiler pressure by means of the equalizing tubes in the oil pipes to the point of delivery at the steam chest.

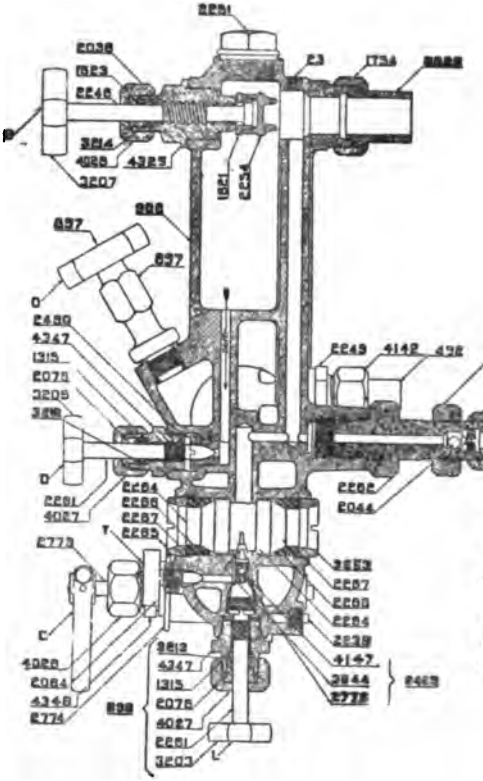


Fig. No. 107

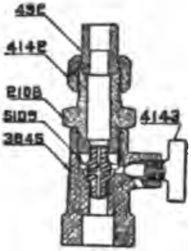


Fig. No. 108

DETROIT BULL'SEYE LOCOMOTIVE LUBRICATOR PARTS

General

492	Fall pipe ½ inch bore
897	Filler Plug
1315	Feed stem ring

1618A	Valve packing nut
1621	Stem valve disc lock nut
1623	Stem valve gland
2038	Stem valve packing ring
2084	Vent stem
2087A	Feed valve stem nut
2238	Water check stop
2241	Drain valve body
2251	Condenser plug
2254	Steam valve disc
2261B	Feed valve stem
2262	Support arm (No. 22 only)
2264	Sight feed glass
2266	Bull'seye glass rubber packing
2267	Feed glass waser
2280A	Air pump choke seat
2489	Feed nozzle, complete
141A	Oil tube
144	Water tube
137	Feed nozzle
141	Oil tube
3519	Filler plug
143	Steam connection elbow
144	Water tube
2279	Choke
2280	Choke seat

Steam Chest Plug

492	Tail pipe
2083	Tail nut
2084A	Vent stem

2109D	1-16 inch Choke
3704	Cap
3845	Body

Detroit Steam Chest Plugs are installed at the point where oil is delivered into the steam way or valve chamber in order that the lubricator may feed against a constant boiler pressure in the oil pipes instead of a pressure fluctuating with that in the steam chest.

The opening in the choke is 1-16 inch, the size necessary to maintain the balance in the lubricator. When the flow of steam through the choke has increased the area of one of the openings to equal 3-32 inch, the choke should be reversed. When both openings are enlarged a new choke should be substituted for the old one.

In the latest type of steam chest plug, the steel choke is threaded and slotted for a screw driver on both ends, thus making the choke secure in the plug, and also permitting its reversal. This steel choke may also be used in the old style of steam chest plug, as the outside thread diameter does not exceed the diameter of the old style of steel choke.

To Start Lubricator—Always start the lubricator about fifteen minutes before leaving the terminal. Be sure that the regular boiler valve is open, then open wide the steam valve at the top of the condenser and keep it wide open while the lubricator is in operation. Allow sufficient time for the condenser and sight feed glasses to fill with water.

Open the water valve. Three turns will give full port opening.

Open the oil control valve "C."

In adjusting the lubricator feeds for a class of service after the oil valve "C" is opened, regulate the cylinder and pump feeds by means of valves "E," "E" and "L." After these valves have once been adjusted, do not use them in the ordinary operation of the lubricator. The oil control valve is employed to throttle the feeds and to shut off part or all of them.

Setting Feed Valves.—Adjust the feed valves to the maximum number of drops required for the hardest level track service in the class. Then the number of drops can be decreased for the lighter service by throttling with the oil control valve.

To Shut Down Lubricator—For short stops, close oil control valve only.

For terminal stops, close oil control valve first, then water valve, and last the steam valve.

To Fill or Refill—Move the oil control valve to "Closed" position, close water valve and steam valve. Open drain valve and fill with clean strained valve oil. If lubricator is under pressure, proceed as before, but remove filler plug slowly to allow pressure above the oil to escape and the air to enter. Fill the reservoir full. If there is not sufficient oil for this purpose, use water to make up the required quantity. This method will expel the air and enable the feeds to start without exhausting the water from the condenser or materially lowering its level.

Steam Valve—The regular boiler valve must be left wide open at all times, and the steam valve at top of condenser must be left wide open while the locomotive is in service.

The Oil Control Valve—The Oil Control Valve is a rotary plug placed in the oil passage between the reservoir and the feed regulating valves, designed for the engineer's convenience for instantly starting, throttling or shutting off the feeds of the lubricator without disturbing the permanent adjustment. This valve has three positions, indicated on the dial.

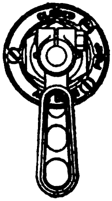


Fig. No. 109

All Open—In this position the passage from the oil reservoir to all feeds is open and the oil will pass through the sight feed nozzles at the rate to which the regulating valves have been adjusted.

To Throttle—By moving the lever handle away from the "All Open" or "Pump" position, the rate of feed to the respective valves can be throttled, if desired. As the valve is purposely made to fit tightly, it may be necessary to tap or jar the valve handle lightly to secure exactly the right adjustment.

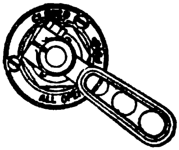


Fig. No. 110

Pump—With the lever handle in the "Pump" position, only the feed to the air pump is left open in the No. 22 lubricator. In the larger sizes only those feeds indicated in the description are working.

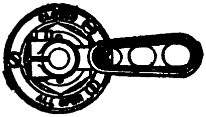


Fig. No. 111

Closed—When the lever handle is moved to the "Closed" position the oil supply to all feeds is cut oft.

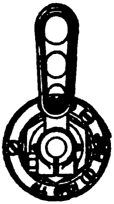


Fig. No. 112

If the valve turns hard, pull and turn at the same time. If oil continues to feed with the lever handle on the "Closed" or "Pump" positions push in and turn at the same time.

A properly balanced lubricator will feed a regular number of drops of oil per minute regardless of the speed of the locomotive. The number of drops per mile, therefore, is in direct proportion to the speed. If the lubricator is set at a rate which will give the greatest number of drops required per mile for the hardest service on level track, heavy duty on grades is automatically cared for by the natural decrease in speed which increases the number of drops per mile. For example: Assume that the hardest level track duty on a run calls for a speed of fifty miles per hour, and proper lubrication requires the lubricator to be set at ten drops per minute; ten drops per minute at 50 miles per hour is equivalent to 12 drops per mile. On a grade, if the speed is reduced to 30 miles without changing the lubricator, the amount of oil delivered to the valves has increased from 12 to 20 drops per mile. After feeds have been set for the hardest service the regulating valves need not be changed during the run, as the number of drops can be decreased for lighter service by throttling the oil control valve.

It is recommended that on arriving at a terminal the water valves be turned off at least fifteen minutes before turning off the steam supply valve. This allows saturated steam pressure through equalizing tubes and oil feed pipes to carry off oil, in the feed pipes. It prevents superheated steam and its accompanying high degree of heat from coming in contact with the water in sight feed chambers and causing it to flash into steam, after which oil carried back with the superheated steam is usually deposited on the sight feed glasses and nozzle tips.

In setting the lubricator feeds before starting from the terminal it is well to allow a good generous flow of oil to the cylinders and air pump for a period of four or five minutes and then regulate them to feed at the desired rate while on the road.

CARE OF THE LUBRICATOR

Much annoyance may be avoided if the lubricator is blown out at least once in two weeks, and a good way to accomplish this is to utilize the condensation that is in the body and condenser when the oil has fed out. The pressure being turned on and all the feed valves closed except one, and the drain valve of that one opened, the water circulates and washes out any substances that have collected around the valve stem and feed nozzle. At the same time, the glasses are cleaned of particles of gaskets and dirt, and sediment blown out. This being done, the feed and drain valves are closed, and the operation repeated for the other feeds, after which the body is blown out through the waste cock and refilled as explained.

Some grades of oil, however, leave a gummy deposit which cannot be removed by blowing steam through the passages. This can be removed only by filling the oil tank and passages with a strong solution of lye. Very strong soapy water will sometimes dissolve this gum, and will not discolor the glasses as will the solution of lye.

It is necessary that the oil be strained before filling the lubricator. To a large extent this prevents the formation of the gummy deposits referred to, and it avoids the possibility of pieces of dirt or foreign matter contained in the oil getting into the oil chamber and eventually stopping up small passages. The opening in the choke plug is not more than 3-64 inch, so that if the oil is at all dirty, this opening soon becomes choked and prevents the proper operation of the lubricator.

In freezing weather, when the engine is not under steam, the water in the cup is liable to freeze and do considerable damage. At such times the water should be drawn out of the sight feed chambers by means of the drain valves, out of the oil passages at one of the plugs and from the oil reservoir through the drain cock, leaving the water valve open so that no water remains in the condenser.

Do not allow any water from the boiler to work into the lubricator. If soda ash or any such scale-preventative is used, it affects the feeds at once. If it works over when the boiler is foaming, the sight feed chambers must be blown out at once through the drain valves and then allowed to fill up with condensed water which is pure and clean.

LUBRICATOR DEFECTS

Stopped Up Feed Nozzles—If a feed nozzle becomes stopped up, the feeding of oil stops. To remedy this, close the regulating valves of the other feeds, open the valve of the stopped feed wide, then close the water valve so that no water comes out of the condenser, and open the drain cock. The steam valve being open, the contents of the sight feed chamber together with the obstruction are blown through the oil pipe into the oil reservoir and out through the waste cock. This being done, the drain cock, and the regulating valve of the stopped feed, should be closed until the sight feed chamber fills with water, after which this feed can be again started. The other feeds may be started as soon as the drain cock is closed. If the obstruction is stuck fast so that it cannot be blown out, then the whole regulating valve with its bonnet may be removed, a stiff wire inserted into the feed nozzle to break up the obstruction and the blowing out process as described repeated with good results.

Stopped Up Choke Plugs—If a choke plug at the delivery end of the feed becomes stopped up, proceed in the same manner as in the case of the stopped feed nozzle, with the exception that the steam valve at the boiler should also be closed and the throttle of the engine opened. This blows the steam from the steam chest back through the chokes and forces the obstruction into the sight feed chamber or up through the equalizing pipes into the condenser. The lubricator is provided with drain valves, and if these are opened the obstruction may be blown out.

Blowing steam back through the oil pipes may make the water in the observation chamber cloudy. This can be remedied by closing the feed valve and regulating valve, and opening the drain valves. Steam passing from the condenser through the equalizing pipe down into the sight feed chambers blows the muddy water out through the drain valves, after which the drain must be closed and time allowed for the filling of the sight feed chamber with clean water.

Irregular Feeding—If slow when working steam and very fast when steam is shut off the engine, it is usually caused by the opening in the choke plugs being worn too large. The remedy for this is to replace the worn choke plugs with others of standard size. It is very useful to have two gauges for the choke plug, one to fit snugly a plug which is known to be of standard size, and another which may be called the "rejecting gauge," which fits a plug worn so that it interferes with the regularity of the feed. Whenever a choke plug is found through which the rejecting gauge passes, the same should be removed from service.

If the passages from the steam valve of the lubricator or steam supply pipes are too small, it also causes irregular feeding, because in that case the full boiler pressure is not exerted on top of the water in the delivery passages back of the choke plug. A steam valve partly closed also causes this trouble. If the choke plugs are of proper size, the steam valves of proper size and the steam valve wide open, and irregularity of feed exists, then the trouble may be caused by pieces of torn gaskets from packings getting into the equalizing steam passages, which must be blown out to remove the obstruction.

Loss of Oil—This trouble is usually caused by mechanical defects in the lubricator, and consists in the oil disappearing from the reservoir when the feed valves are closed, and the water and steam valves open.

It may be caused by a small blow-hole in the casting, forming a passage from the oil reservoir into the condenser, or into the upper delivery arms of the lubricator.

In such cases the oil is forced through these blowholes from the top of the reservoir without first passing down through the oil tubes and through the regular feed channels. Such openings may be original defects, but they may also develop as a result of careless handling or freezing up of the lubricator on a cold engine.

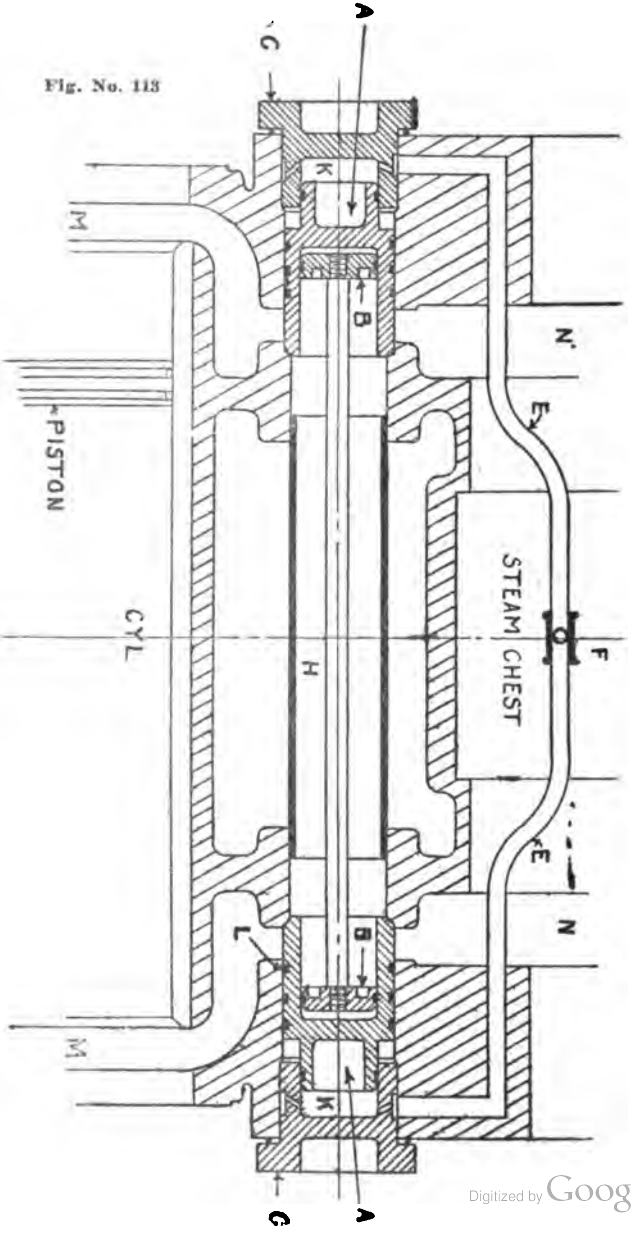
The disappearance of the oil may also be caused by a defective water pipe or by an improper joint where the water pipe screws into the casting at the upper end of the pipe. In such cases the oil flows into the condenser and disappears unseen by the operator.

Defective Gaskets—In case a gasket is defective, so that oil or water leaks around the sight glasses, and in case tightening up the gasket by screwing in the follower does not stop the leak, the oil is drained and the reserve glass put into the place occupied by the defective one. Sometimes it is necessary to change glasses on account of them being so dirty inside that the rate of feed cannot be observed. For this defect a small piece of yellow soap placed in the sight feed chamber has been found a good remedy.

BY PASS VALVES

Figs. 113 and 114 show the modern by pass valve used on large engines today. Referring to the diagram we have the steam ports M M connected together by means of the tube H; the by pass valves A A moving in the cylindrical portions of the chambers K, having a dash pot piston at B to prevent slamming and resultant breakage. A vent port not shown to which pipes are attached is used to relieve any pressure in H, also to indicate when the valve sticks open for any reason. When starting the train this blow can be stopped by pulling the reverse lever up near the centre. This will close the steam port M and

Fig. No. 113



take the pressure off from the inside of the valve; then the pressure acting through the pipes E E will build up pressure enough in chamber K to force it closed.

Operation of the valve is very simple. When the throttle is open, steam from the chest passes through the T connection, F branches off through the pipes E E, admitting steam to the end of the valves at K K. This pressure forces the valve over on to its seat, closing the connection through H.

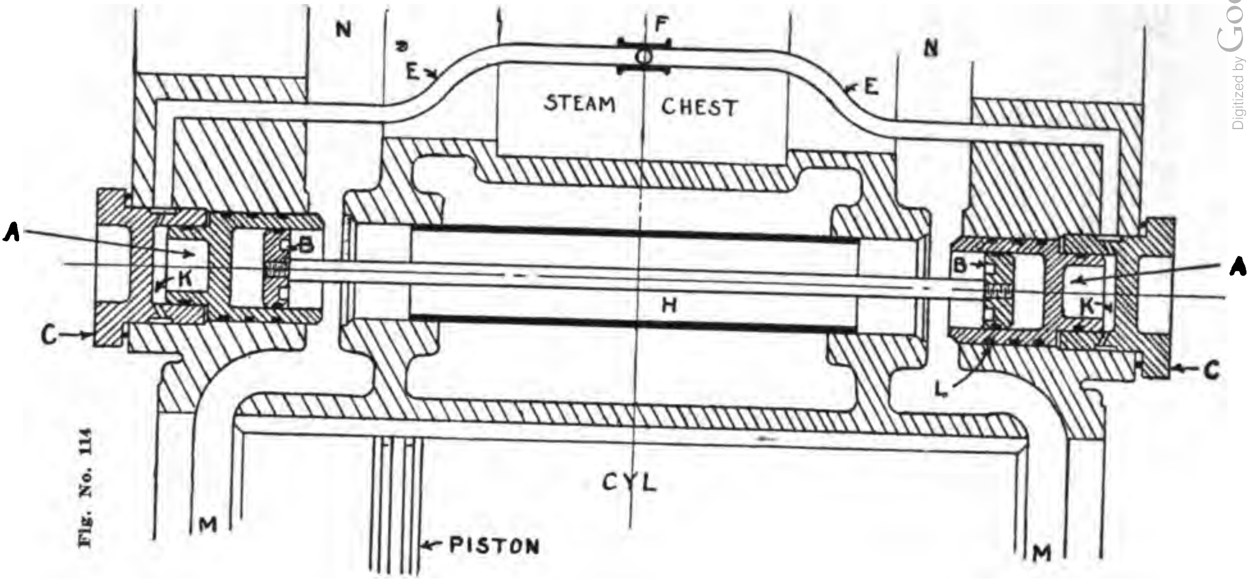
When steam is shut off a slight vacuum is formed in the chambers K K; this and the cylinder compression opens the valves as shown in Fig. 114, and causes an opening to both ends of the cylinder through H, as shown in Figure 114.

When the engine is drifting the air compressed in one end of the cylinder after the steam port is closed will be passed up through the port and the tube H to the opposite side of the piston; this air relieves the vacuum on the opposite end of the cylinder, that is, it passes the air by the piston and therefore derives its name (the by pass valve) from the duty it performs.

BROKEN BY PASS VALVES

In case a by pass valve becomes broken the valve will stay open since the pressure on the inner side of the valve will have a greater force; for example, the steam will pass by the piston B and build up on the inside of the cylinder portion. This will overcome the pressure entering from the steam chest at K and hold the valve open. The steam entering the cylinder M will flow through the tube H, open the by pass

Fig. No. 114



valve on the opposite side, and since the opposite side has the steam port connected to the exhaust port by the cavity of the main valve, here we get a direct connection to the atmosphere and a very strong blow is indicated at the stack.

The remedy is to remove the opposite cap C, fit a piece of wood between the cap and valve, replace the cap, making up tightly on the flange bolts to prevent steam leakage at the flange. This will hold the valve firmly on its seat but, of course, the engine will not drift as freely; at the first opportunity the valve should be renewed.

Broken steam pipe E—It will be necessary to flatten the pipe down with a hammer to make a quick repair on the road, and block the valve closed as described before.

Should both branches be broken, to repair quickly, flatten the pipes and block any one of the valves closed; this will prevent the steam blowing by through the tube H and out the exhaust, as already described.

NATHAN AUTOMATIC VACUUM BREAKER OR DRIFTING VALVE

When a locomotive is coasting or drifting it is imperative that the vacuum created in the cylinders should be broken automatically to produce the following extremely desirable results:

1. To exclude hot gases, cinders, etc.

2. To prevent carbonization of the lubricating oil.

3. To prevent knocking and straining of the reciprocating parts and to cushion the pistons at the end of each stroke.

These results are accomplished by the vacuum breaker automatically, by admitting steam, the proper medium for the purpose into the valve chambers and cylinders, directly from the boiler, whenever the engine is running with throttle closed, as when entering a station or a terminal or drifting down a grade. This automatic admission of steam takes place at the instant that the pressure in the cylinders drops down to below ten pounds per square inch. On the other hand, no more pressure than this can be built up in the cylinders, because as soon as the pressure reaches ten pounds per square inch, further admission of steam is stopped automatically.

The foregoing effect is brought about by the difference in areas against which the steam acts at each end of a differential piston arrangement. It is to be noted that the vacuum breaker does not break the vacuum after it has been formed even for an instant, but forestalls the formation of any vacuum by the properly timed admission of steam into the valve chambers and cylinders when the throttle of the engine is shut off.

A small oil cup is furnished with and is attached to the vacuum breaker so that the internal moving parts may be kept well lubricated.

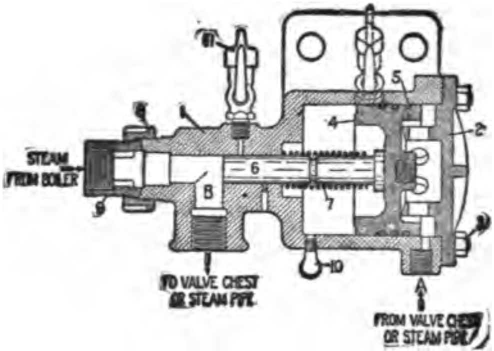


Fig. No. 115

No. of Part	Name of Part
1.	Body
2.	Cover
3.	Stud and Nut
4.	Piston
5.	Piston Ring
6.	Plunger
7.	Spring
8.	Coupling Nut
9.	Tailpiece
10.	Drain Elbow
11.	Oil Cup

VACUUM BREAKER OPEN

When the pressure in the valve chests or cylinders drops down below ten pounds per square inch, the boiler pressure against the plunger 6 moves the same and with it the piston 4 to the right far enough to uncover the passage B and admit steam from the boiler into that passage and into the pipes which from that passage lead to the valve chest or steam pipe on each side of the engine. This admission of steam continues until a pressure of ten pounds per square inch is built up in the valve chests and cylinders when the piston and with it the plunger will move back into the closed position.

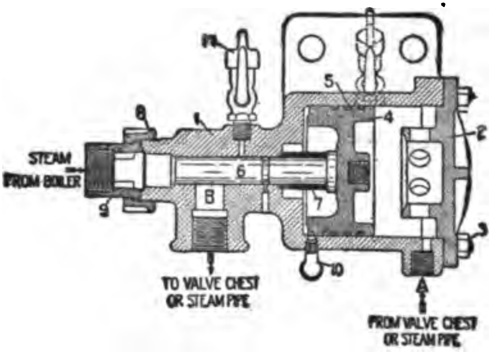


Fig. No. 116

VACUUM BREAKER CLOSED

Engine throttle being open, steam from the steam pipe or valve chest enters at A and moves the piston 4 and with the plunger 6 to the left far enough to cover the passage B so that steam from the boiler cannot enter that passage, and the pipes from that passage lead to the valve chest or steam pipe on each side of the engine. This condition prevails until the throttle is closed and the pressure in the valve chests and cylinders drops down to below ten pounds per square inch.

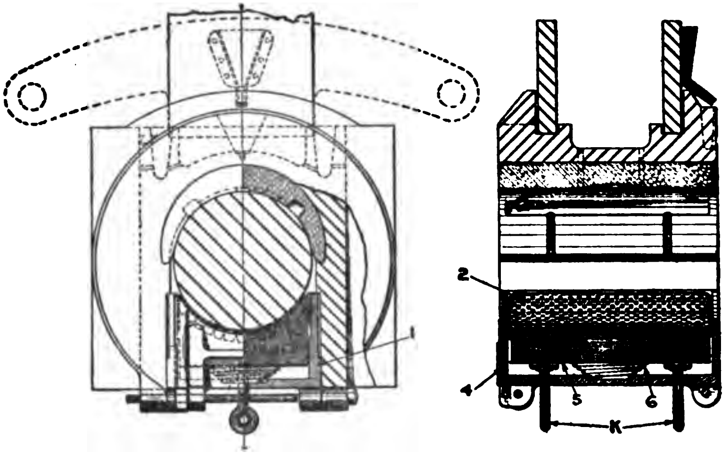


Fig. No. 117

THE FRANKLIN DRIVING BOX LUBRICATOR

The Franklin driving box lubricator is used extensively on railroads today. It is a simple device as will be seen by referring to Fig. 117. We have a cellar 4 and a grease compound made to fit the journal resting on a plate 5, having a spring 6, under pressure resting on the bottom of the grease plate 5 and indicators K, passing through the base to show the quantity of grease present at all times. A copper screen 2 is used against the journal through which the grease is fed.

Engines equipped with this device rarely run hot, although the running temperature is generally higher than oil-packed driving boxes. It is seldom that we hear of this type of lubrication giving trouble.

Should the bearing start to heat, however, it is generally caused by the grease feeding out of the cellar or the screen stopped up. In such a case it should be removed and washed off with the wet down hose, making sure that it fits the journal when placing it back in position.

If the grease is found to be fed out a little cup grease of the same kind can be placed between the screen on a journal, provided the distance to go is not great.

TENDER JOURNAL BEARINGS

Most hot box trouble on locomotive tenders is traced to improperly fitted journal bearings as a result of excessive wear at one point on the journal.

In case of a hot journal bearing on a tender .it will often be possible to pack the hot box with hard cup grease, cooling the journal before applying the grease. This will help to get the train to a point where the journal brass should be changed.

When the journal is very hot it is bad practice to use too much water or suddenly cool it; this will often cause small cracks to develop and serious consequences result from a future broken journal. The following is a summary for the care of journal bearings:

THE JOURNAL BEARING

The bearing should be made of proper material to prevent cutting the journal when the bearing wears through the babbitt lining; the crown of the brass should be straight to provide for a good wedge bearing. The brass should be bored parallel with the crown, having not less than 1/16" width chip for tinning and the babbitt lining. The lining should be perfect and parallel with the bore of the shell and gauged properly the whole length. Several leading railroads bore or roll smooth the linings to insure a perfect fit to the journal.

THE JOURNAL

The journal should be straight. Better the finish, better the wear and less hot box trouble. Front and back fillets should be looked after to avoid scouring the ends of the brass. If the oil-box pedestal is out of alignment, it should be corrected.

PACKING WASTE

Packing waste should be long strand, with sufficient amount of wool to give proper resiliency and maintain a correct wick-fed or capillary power to convey oil to the journal from the bottom of the box. It should be soaked in oil 48 hours, then drained suitable for use.

METHOD OF PACKING

Before packing a tender, first apply a roll of suitable size, saturated in oil, to the back side to exclude dust from the journal box. Next, firmly pack the box to the height of the centre of the journal, and leave a small "plug" or piece of waste at the outside of the box to hold waste already packed. Never leave waste strands hanging from an oil box. Always see that journal box lids are applied.

WORKING STEAM EXPANSIVELY

The proper method of running a modern locomotive is by use of steam expansively in the locomotive cylinders, because, as explained in the pages on Heat and Steam, it requires but little addition of heat to the water to double the pressure, between the steam at 100 pounds and that at 200. High pressure in the locomotive cylinders is capable of expanding greatly when full boiler pressure is admitted for a short period of the stroke cut off and caused to expand and pass out the exhaust at a lower pressure.

When steam is throttled down between the boiler and cylinders it will reduce the available expansive force because the temperature is reduced in passing to the cylinders; that is, you cannot reduce the pressure of steam without diminishing its temperature; then it is plain if we are to work the engine with a lower pressure in the cylinders than that available from the boiler we might as well carry less pressure on the boiler.

Modern valve gears do not show any economy when operated at shorter cut off than 30 per cent. Of course, with light trains the steam must, under some circumstances, be throttled down.

On the other hand, some engines tend to prime with a full throttle opening, and since priming uses up more water, the increase dampness of the steam will require more water to be put into the boiler and hence more fuel burned.

All engineers do not run the throttle fully open and short cut off on large engines because there are many disturbing conditions, for example—there may be considerable slack in the valve gear; this vitally affects the working of the engine when the valve travel is at its minimum working point. Often there will be but three exhausts due to short travel of the valve caused by a loose or worn radius bar hanger or a worn link hanger or pin, or slack at other points in the valve gear.

Under the above circumstances the engineer is compelled to work the engine at longer cut off than is necessary and throttle down to regulate the speed.

STARTING THE TRAIN

When starting the train the reverse lever should be in full gear, hooking up gradually, that is, one or two notches at a time until the running notch is reached.

This plan will help the lubrication on valve seats, will allow the steam to form a film between the valve and seat.

GETTING OVER THE HILL

Some engineers make a practice of getting a run for a hill, but do not begin to drop the reverse lever soon enough. For example—assume that we are ascending a grade of 20 miles per hour; the speed gradually drops to 15 miles per hour and cut off is not changed. Here we find the boiler is not being called upon for as large a quantity of steam as before. It follows, therefore, when the speed of the train starts to lag the lever should be advanced another notch to hold the speed up as much as possible, gradually increasing cut off as speed decreases.

By dropping the lever the engine will keep up the momentum of the train, whereas letting the force of the train drop down too low before dropping the lever, the engine will have to be worked harder over the hill, that is, it will have to work at longer cut off for a greater distance than would be necessary had the cut off been lengthened before the train had reduced speed greatly.

CARE OF A LOCOMOTIVE BOILER

The engineer and fireman should be careful in pumping or supplying the boiler with water, keeping a uniform level so far as possible to insure steady steaming. It is well to remember that steam is generated by heat, and heat is measured by its B. T. U.'s, explained herein; that is, the more water we carry the more stored-up heat we have in the boiler and, consequently, the less change in temperature will result when cold water is introduced to take place of the steam leaving the boiler.

The engineer should, however, co-operate with the fireman by favoring him (so called) by shutting off the water while he is using the firehook or bar, and steam is below the desired point. He should never run the injector while starting out of a station because this will run the steam pressure down since the demand for steam under these circumstances exceeds the supply.

Of course, it must be remembered that there is such a thing as overdoing it by carrying too much water. This will result in boiler priming. It is safe to say that 2½ gauges of water is about as good as can be had with the average locomotive boiler, good water conditions and clean boiler included. If the engineer is not careful about the water level and allows it to get so high that he is working wet steam, it is bound to increase the work of the fireman, because each pound of steam will have a greater content of water; it will, therefore, be necessary to evaporate more water to supply the demand of the boiler and it will be seen that the relation of water evaporated per pound of coal is bound to drop. (See also chapter on Superheat Locomotives.)

Before leaving the terminal or engine house, the engineer should inspect the locomotive boiler to see that no defects exist and the following method of inspection is recommended:

First, see that the boiler has a good supply of water.

Second, see that the tubes or flues are not leaking; the crown sheet and all inside portions of the firebox are tight, especially arch tubes.

Third—Try both injectors to see that they are working properly. Blow out the water glass thoroughly by first closing one valve and then the other, noticing if there are any steam leaks at the valves or glass connections which would tend to give a false water level, try gauge-cocks. I have known of a case when an engineer kept the water glass valves partially closed and a leaky upper steam connection packing nut on the water glass caused the pressure on the top of the water in the glass to become slightly less so that the water was forced up much higher; this false water level resulted in a burned crown sheet. If the gauge-cocks were used to check the water glass this would have been prevented.

Fourth—See that the ashpan is closed and properly cleaned and the front end door is secured tightly and no air leaks are existing.

Fifth—Oil the boiler expansion plates or pads. See that the throttle packing is in good condition and no excessive steam leaks in the cab. Some engineers in pooled service make a practice of noticing the cab boiler certificate to see if the boiler is due for a washout. This is a good plan and should be encouraged.

Sixth—Broken staybolts, leaky mud rings, defective ashpans, disconnected grate bars, and any defects in the air operated firebox door should be promptly reported if found unfit for service.

Seventh—The steam gauge should be inspected to see that it is fastened securely and no steam leaks in the piping leading from the boiler; also the condition of the safety valves and note the pressure at which they open and close.

On the road the engineer should not open or close the throttle quickly. This will throw excessive strains on the boiler; many attribute broken staybolts to this cause. Many cases of broken cylinder heads have resulted from quick throttling, since there is a strong tendency to lift the water over into the cylinders when the steam suddenly rushes out.

REPORTING WORK ON THE ENGINE

The proper and intelligent work report oftentimes shows the type of engineer. Many men do not realize how important it is to the terminal forces to have the defects stated with exactness and how important it may be to the man taking the engine out the next trip to know just what work has been done and what, if any, has been neglected or overlooked.

Work reports showing the following give no desired information and should not be so placed on the book without stating the location or cause as far as the engineer is able.

Engine pounds bad.
Engine blows bad.
Engine don't steam.
Lubricator don't feed.
Injector will not work.

A proper report would read, "Engine pounding, set up left main wedge."

Engine blowing, left forward by pass valve broken.

Engine does not steam Supeheater flues need cleaning, air leak at steam pipe opening on left side of smoke box.

Lubricator choke plug on left side should be cleaned.

Tighten suction pipe connection on right injector, clean the tank, etc.

LOCATING BLOWS

Testing for defects such as blows is a matter requiring considerable skill on the part of the engineer and is a very important requirement to assist in properly and quickly making repairs. An accurately reported defect of this kind may save as high as 10 or 15dollars in unnecessary labor to say nothing of the loss of the service incurred by the locomotive.

Blows in the main slide valve or seat may be tested by placing the engine on the top quarter with the lever in mid position, admit steam to the chest (having the brake set in all tests) open the cylinder cocks, steam appearing here will indicate a cut valve or seat provided, however, the engine has no inside clearance, that is, main valves having cut seats or faces and inside clearance would tend to blow at the stack because the exhaust and steam ports would be connected by the cavity of the valve and there would be a greater tendency for the steam to blow into the exhaust port and out the stack. The best way to try the tightness of the main valve having clearance would be to incline the reverse lever in full forward gear with cylinder cocks open and steam admitted to the cylinders, then slowly pull the lever back until the port is closed which will be indicated by the stopping of the flow of steam at the cylinder cock to a considerable extent. Then giving the engine more steam a leakage, if any, will be observed at the cylinder cock.

It will be necessary to test each side of the valve in the manner described, first trying the front edge of the valve and then the back which will be accomplished by placing the lever in the back gear and proceeding as before described and then trying the valve on the other side of the engine in the same manner.

Blows by the packing strips of the American Balenced or the Allen Richardson valve, a broken valve strip spring will often make the defect known by the way the engine handles. For example—the purpose of the strip and spring is to prevent the pressure from getting on top of the valve and therefore when pressure does accumulate on top, it will cause it to move much harder and when the engine is working will often pull the reverse lever away from the engineer when he is trying to hook up. To test for this defect, place the engine on the quarter reverse lever in mid position, give the engine steam and notice whether there is a screeching sound, if so, it will generally indicate a packing strip defect.

Next, to find on which side the defects exists. Sometimes after the end of a run the eccentric strap on the defective side will be found warmer than the one on the good side. To make sure the engine should be set as described above, admit steam to the chest and open a saddle cock, the one having the greatest amount of steam blowing will generally indicate that it is the defective one.

There is also another test by placing the engine on the quarter, first on the right side, then on the left, reversing the lever first from one corner to the other, noticing on which side of the engine requires the greatest amount of force necessary to move the valve, the one requiring the more force indicates it is on that side.

TESTS FOR BLOWS IN CYLINDER PACKING

Place the engine on the quarter lever in full gear, admit steam to the cylinders and open the cylinder cock on the opposite end of the cylinder to that where steam is acting against the piston. Any leakage by the packing rings will be indicated at the cylinder cock. This will also cause a blow at the stack, sounding like that of the blower.

Blows in the cylinder packing can also be determined when the engine is starting a train. For example—when the engine is working hard there will be a strong blow up to the point of cut off and from there to the end of the stroke much lighter, the defective side can be found by watching the crosshead while starting the train.

BY PASS VALVE BLOWS

Since the introduction of by pass valves of the type shown in Fig. 113 there has been much confusion as to whether a blow sounding like that of a cylinder packing defect is caused by a broken by pass valve or a cylinder packing ring. It will be noticed that the by pass valves connects both steam ports together when open and a broken valve will therefore let the steam pass by the piston to the opposite side and since the opposite side is connected to the exhaust port there will be a long continuous blow like the foregoing defect.

To test for the defective by pass valve, place the engine on the quarter with the lever in full gear, admit steam to the cylinder. Should a blow occur place the lever in the opposite corner. This will close the steam port on the side of the piston that took steam in the first test and will cut the by pass valve out on that end of the cylinder, open the steam port to the exhaust and admit steam to the opposite side of the piston.

Should the cylinder packing be defective or the cylinder scoured there will be a blow with the lever in both forward and back gear, but the defective by pass valve being shut off by the main valve as the lever is reversed the answer is a blow will occur in one position of the lever, that is, there may be a blow when the lever is ahead but will stop when placed in the back gear, the defective valve being on the end of the cylinder where the engine takes steam and the blow is indicated.

TESTING FOR POUNDS AND RESULTS OF NEGLECTING.

To locate a pound in driving boxes and rods, place the engine on the top quarter on the side you are to locate the pound, set the tender brake if the engine has no tender hand brake and is equipped with the Westinghouse E. T. or New York L. T. brake equipment, cut out the driver brake, apply the independent or straight air brake valve, then give the engine steam and have the reverse lever worked from extreme front to back gear.

Watch the driving boxes, wedges, main rod ends, crosshead shoes, knuckle pins, and note the movement, if any, between the journals and driving boxes.

The engine should be set on the top quarter because of the greater advantage the steam in the cylinder has over the weight imposed on the driving wheels, as explained in Fig. 126.

For example—when steam is admitted to the cylinders, the engine standing on the top quarter, it will be necessary to revolve the wheel to take up the slack in the driving boxes, whereas on the bottom quarter the whole engine and frame will be moved. A trial of this will convince the reader beyond doubt.

A further reason for placing the engine on the quarter is that steam can be admitted to both sides of the piston alternately by changing the position of the reverse lever.

Sometimes in the older type of engines the saddle key may become loose. It is a good plan to notice this while making the test. Frame fractures should be looked for, especially between the main driving boxes and cylinder saddle; it is also convenient during this test to check up the slack between the engine and tender and note the condition of the buffing device. Slack or loose wedges are a menace to good locomotive performance, and especially so when the main wedges are run loose; this throws the work on the side rods and after a few trips the knuckle pins and rod bushings will be ruined. Many broken side rods and main frames are traceable to the above because the act of pounding causes crystalization of the material under strain. The writer has personally investigated cases where main frames, having eleven times the strength of that imposed upon them, failed simply due to the excessive vibration as a result of the engine pounding, causing the frame metal to fatigue and break.

Sometimes through short sighted policy of the terminal forces rod bushings, knuckle pins will be renewed and often wedges lined down and at the same time no attention paid to the condition of the main driving box brass; with side or parallel rods in good condition and slack main wedges or boxes the rods must take up all the shock and consequently little service is rendered before the work must be repeated.

ENGINES POUNDING WHEN STEAM IS SHUT OFF.

Whenever an engine pounds drifting with steam shut off, it is generally due to overtravel of the piston in the cylinder far enough to strike the head. This may also be due to a broken cylinder packing ring where the broken ring may work out of the grove and drop down into the cylinder or counterbore a loose nut, or a follower bolt as used on the older types of engines.

Whenever a pound of this kind develops on the road, the engine should not be entirely shut off while making a station stop, the lever should be kept well hooked up. This will give greater cylinder compression reducing the blow or eliminating it entirely. It is a good plan in case it is necessary to shut off steam in making the station stop to have the brake applied before the throttle is closed, this will force the driving wheels back provided the engine has the foundation brake gear with the brake shoes ahead will take up some slack causing the driving wheels and piston to move to the back slightly. However, this will only remedy a condition where the piston is striking the forward head; in case the trouble it with the back head being stuck by the piston, matters would be even worse.

The side on which the engine is overtraveling can be determined by watching the crosshead as it passes the centres. There are, of course, instances where any of the foregoing remedies cannot be applied; in such a case the main rod should be taken down and the piston blocked ahead or the cylinder head taken off and the obstruction removed. While this cannot be conveniently done on the road with the heavy engines now used, it, therefore, is advisable to get the engine into a terminal if possible, without disconnecting, making the movement light if necessary.

SETTING UP WEDGES

To set up a wedge, place the engine on a straight and level track, having the main pin on top quarter on the side you are to set up the wedge; set tender brake; place the lever in forward gear and give the engine just enough steam to pull the driving box away from the wedge; then raise the wedge as far as it will go and slack it back about one-eighth of an inch to guard against it sticking.

The wedge should be properly lubricated then to prevent sticking and hard riding; wedges should never be set up when the engine is cold, because the frames may expand and cause the pedestal jaw to bind the driving box.

New engines are now equipped with the Franklin self-adjusting wedge. This device has helped greatly in the maintenance of driving boxes.

KEYING RODS

To key up a back end of the main rod place engine on the top forward eight, slack the set-screw and the drive key. (This is generally the largest diameter of the pin.) See that it is all free, and you can move it sideways. Key in this position, because all that will be necessary is to move the brass next to the key and the weight of main rods will be on the opposite brass due to the angle. Key the forward end on the centre, and key in like manner; it might be larger at that point.

It is often convenient to key engines having the key behind the main pin by setting them on the lower quarter and admitting steam on the forward end of the cylinder; this will take up the slack and remove the weight from the brass to be keyed or moved. This plan is also used where the key is ahead of the main pin, but, of course, the lever must be reversed so to pull on the strap brass and relieve the one to be keyed.

The same plan can be used on the forward end. For example—Lever in back gear giving the engine steam on the lower quarter will pull on the strap end of the main rod and relieve the weight from the brass next to the key and therefore can be moved up much easier.

After the work is done the back end should be put on the upper eight and see that it is not too tight, as explained. The forward end should be tried also at the centre and see that it is not too tight there.

ENGINES SLIPPING

Handling the engine on a slippery rail requires considerable patience. A light use of sand will usually hold the driving wheels, although there are times when the throttle and reverse lever must be operated to prevent slipping.

Generally on long stroke engines, slipping can be prevented by working at short cut off and moderate throttle. For example—an engine having a 30-inch stroke and a cut off at 30 per cent. will bring the point of cut off at 9 inches. When the crank pin passes the quarter the steam will have expanded to a lower pressure, lowering the force of turning the wheel at the point (the quarter) where the greatest turning effort and the greatest tendency toward slipping occurs.

Of course, one of the most prominent causes of slipping are leaky cylinder cocks dropping water on the rails causing the adhesion of the wheels to be less. The same is true of leaky tanks when backing up.

Some engineers prefer to run a long cut off and light throttle. This plan is also a good one, the only argument against it, however, is for example, assuming the pressure against the piston to be constant, as the crank pin approaches the quarter the leverage will increase and the tendency to slip will be greater whereas, with the short cut off the pressure in the cylinder will have decreased as the pin reaches the quarter giving practically the same turning effort.

APPLYING SAND

Sand should be applied on both rails because sand used one side will often cause the engine to be stripped on the side sand is used on. Sometimes engines having excessive lateral play will often buckle the side rods on the side sand is used on.

Engines should never have sand applied while slipping, steam should first be shut off and sand applied after slipping stops.

HARD RIDING ENGINES

Many hard riding engines are traceable to insufficient lubrication of wedges that is where the oil does not work down to the bottom of the wedge. Often wedges will become cut or ridged from the above cause. The use of thinner oil will often help such a situation especially in cold weather mixing the engine oil with a fairly large amount of signal oil or kerosene.

When the engineer has a regular engine assigned it is often convenient to run kerosene down between the wedges and shoes, thus cleaning out the congealed oil and removing some of the dirt.

Then allowing an hour or two or even more for the kerosene to run off before applying the lubricating oil, this practice will often improve the riding qualities of the engine.

Oiling equalizer fulcrums or pins is often overlooked, they should receive lubrication and when oil holes are not provided, the same should be reported and attended to when the engine goes to the back shop for repairs.

Loose wedges, worn driving box brasses and worn rods contribute to hard riding qualities of the engine.

STUCK WEDGES

Hard riding engines result from sticking wedges and it is often difficult to pull them down to their proper position, when they become bound up tightly between the driving box and frame.

The following method is used referring to Figs. 118, 119:

Block temporary over the driving box ahead or behind in the manner shown, then run the driving wheel up on a wedge, the one that you have blocked, as shown in the figure, this will lift that side of the engine up away from the driving wheel having the stuck wedge, or in case the wedge is badly stuck the wheel on that side may be lifted with the frame. Generally a badly stuck wedge will cause the driving box to heat, this being due to the pounding it receives at rail joints or other uneven portions of the rails. In such a case the proper method of pulling the wedge down is to proceed as before and if the wheel is lifted from the rail and there is plenty of time let the engine stand on the wedge and as the driving box cools off it will contract, then the weight of the wheel itself will pull it down.

The wedge should then be set properly to prevent a recurrence of this kind.

EFFECT OF COUNTERBALANCING

Whenever changes are made increasing or decreasing the weight of rods it will often be manifested by the way the engine rides. While it is not the intention of railroads to overlook this there are often found types of engines with rods that can be interchanged and by mistake the wrong one applied. When an engine has rods too light for the counterbalance it will cause the engine to lift at the rear giving an up and down motion on the spring rigging. Whereas, when the counterbalance is too light the engine will tend to nose or move up and down on the spring rigging ahead.

A quarter slipped engine is an engine having a worn space on the tire produced by excessive slipping at the point where the greatest tendency toward slipping occurs. For example—an engine taking steam at the eight will generally have pressure exerted against both pistons; here we have a tendency to slip because the pressure tending to move the wheels is greater and slipping may take place for a short portion of the revolution of the wheel. Where this takes place many times the tires will often become worn for a short space giving the tire an eccentric-like action.

Quarter slipped engines will often cause broken rails on account of the increased hammer blow action caused by the engine while traveling over the rails.

The engine, of course, will ride excessively hard.

Engines of the Micado Pacific and Santa Fe types often ride hard; the cause is directly traceable to improper trailer truck maintenance. For example—worn trailer truck radius bar pins or excessive slack at the forward swivel point will cause considerable vertical movement. Centering devices disconnected an insufficient lubrication on the friction plates contribute to the hard riding qualities of the engine.

Often trailer truck tires will be found shimmed out of round. For example—(due to some careless workman), shimms will be applied too thick on one side of the wheel while the tire is heated and when cooled the tire will be slightly out of round giving it an ecsentric-like action.

The above defect can be determined by carefully calipering the tire or by use of a gauge working from the center of the trailer truck axle to the tread of the tire.

LOCOMOTIVE ACCIDENTS OR BREAKDOWNS

One of the first duties of an engineer when a breakdown occurs on the road is to protect the train by flag if necessary, clear the main line as soon as possible, preventing as little delay to traffic consistent with the nature of the accident.

The skill and judgment of an engineer is often manifested by the manner in which he handles difficulties of this kind, he should take measures to prevent them as far as possible, by careful inspection of the engine before leaving the terminal.

While there are many heavy breakdowns that the engineer cannot remedy on the road with the limited assistance and tools generally available, he is however, expected to be able to properly supervise and direct the work when men are sent to repair and bring the engine into the terminal. It is therefore essential that the engineer be familiar with the remedies applicable to various locomotive breakdowns because thousands of people may be inconvenienced under circumstances where he may fail to apply the proper judgment. Spring rigging breakdowns seem to be the hardest to understand and it is essential that the manner of suspending the locomotive be understood.

Most of the heavy breakdowns are a wreck train job on the modern engine. However, the engineer should be familiar with their treatment.

The following pages will describe briefly the various breakdowns on the most common types of locomotives used today.

Generally, modern locomotives have the weight of two or more driving wheels equalized together so that an unevenness of track will not put too great a shock on one spring but will equalize some of it to the other wheels.

BREAKDOWNS BY TYPES OF LOCOMOTIVES

A careful study should be made of spring rigging accidents since they generally are most difficult to understand. Some men figure out in their own mind just how the spring or equalizer will go when a spring or hanger breaks. In general, with any type of spring rigging the broken hanger will cause that end of the equalizer to go down whether the engine is overhung, underhung, or hung between the frame rails.

On Mogul type engines the lead truck and forward pair of drivers are equalized and the No. 2 and 3 driving wheels separately from the front pair.

Consolidation engines, the lead truck and Nos. 1 and 2 driving wheels are sometimes equalized together but in some cases the lead truck and No. 1 pair as in the Mogul type.

Pacific and Micado types are generally equalized with the trailing truck and the last two pair of driving wheels. The forward No. 1 and 2 pair of driving wheels of the Micado are generally equalized together. Some Pacific types will be found equalized clear through, that is, all driving wheels and trailer trucks will be connected without any rigid points in the spring rigging.

Same is true of some of the Micado types.

TRANSFERRING WEIGHT

By running up any driving wheel on a wedge the driving spring attached to that driving box will be put under compression, pulling the equalizer up or lifting the spring saddle up above normal. Should the engine be of the overhung type a block placed between the saddle and frame rail will take up the load carried by the driving box and transfer it to the frame when the engine is run off from the wedge and of course the frame will distribute it along to the other springs.

Engines of the underhung type can be made to transfer the weight from one driving wheel to the other by chaining the equalizer to the frame rail or blocking the equalizer between the end next to the driving box and the safety hanger. The weight is then thrown on the main frame and will be distributed to the other driving boxes.

Often it will be found impossible to entirely relieve one driving box of its weight because the excessive strain placed on the other springs, will compress them beyond their normal position. It is often convenient to block between the driving spring and saddle for hot driving boxes, since the block will transfer a good deal of the weight to the other wheels and the driver will have to bear but little of its original load.

Often tire breakdowns, as shown in Figure 124, will be necessary to block over good driving boxes on account of settling of the main frame in the manner explained in the foregoing example. In such a case the blocking should be placed on more than one wheel in order to distribute the wheel load as equally as possible.

Figs. 118-119 shows the method for raising an engine up in case of a broken spring or hanger or an overhung engine but is also applicable to an underhung type.

Referring to Fig. 118 shows the broken spring hanger; Fig. 119 the diagram shows the position of the wedge under the main driver. Since the main frame dropped down on top of the driving boxes it

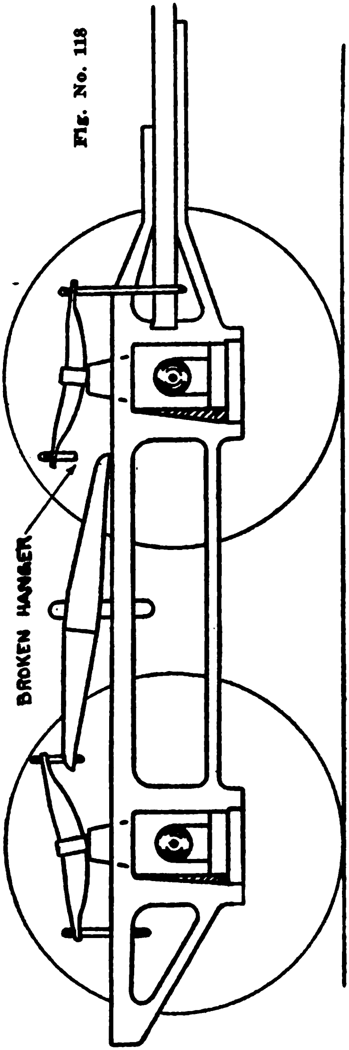


Fig. No. 118

will be seen that running the main driver up on the wedge as shown will raise the engine up the thickness of the wedge and the distance it is so raised up will give a space between the back driving box and frame into which a temporary block No. 1 should be inserted as shown.

Then running the engine off from the wedge under the main driver and placing it under the back driving wheel as shown, the engine run up again will give a space equal to the thickness of the wedge and temporary block No. 1 over the forward driving box and between the frame into which a block No. 2 should be inserted as shown. When the main driver is run up on the wedge as described in the first example the equalizer should be pried up and a block (No. 3) inserted betwen it and the frame rail as shown.

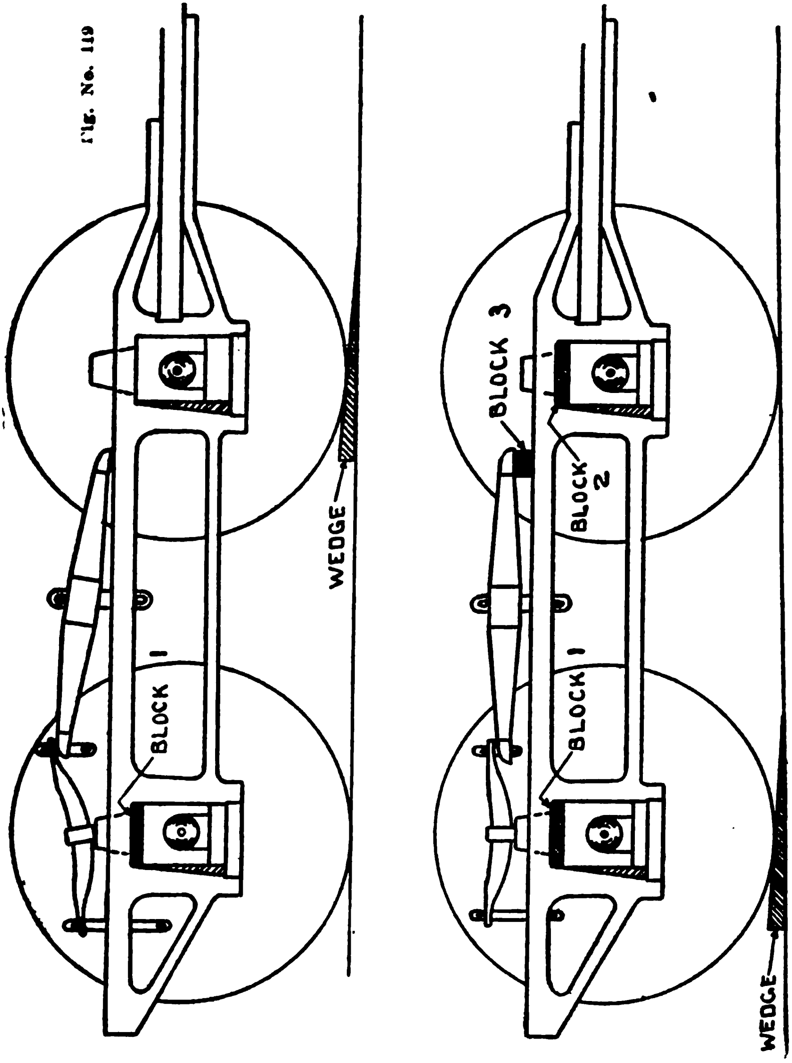
The same method is used on an underhung engine except the equalizer should be chained to the lower rail of the frame instead of using block 3 as shown in Fig. 121 (D).

In cases where hardwood can be obtained it should be used to run the engine up on, another method is to use fish plates laid on one another in a step like manner so the driving wheel will run up on first one and then the other.

Fig. 120 (C) shows the method of handling a broken main driving spring on an overhung engine. Fig. 120 (A) shows the method of handling the same breakdown on an engine hung between the frame rails.

In each case proceed to raise the engine up as explained in Fig. 119, and insert a block over the main

Fig. No. 119



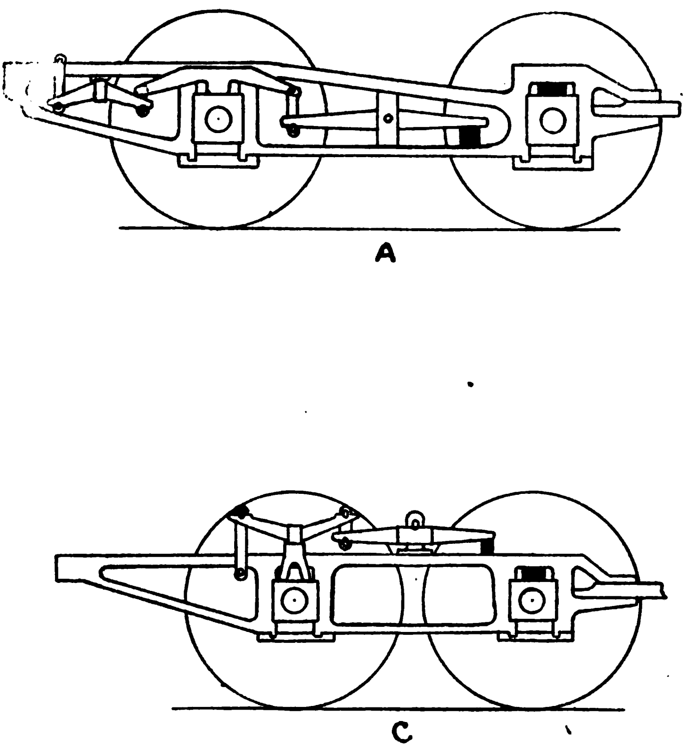


Fig. No. 120

driving box as shown and block the end of the equalizer as shown here.

Fig. 121 (D) shows a broken main driving spring or hanger on an underhung engine; simply proceed as with the foregoing types but chain the equalizer up to the lower frame rail as shown instead of using blocking.

Fig. 121 (B) shows the method of blocking for a broken back driving spring or hanger on an overhung engine. Proceed by raising the engine up as explained, block over the back driving box and back end of the equalizer as shown.

Engines of the Mogul consolidated or Micado types proceed the same way, only block both loose equalizer ends instead of just one as shown in the foregoing figures.

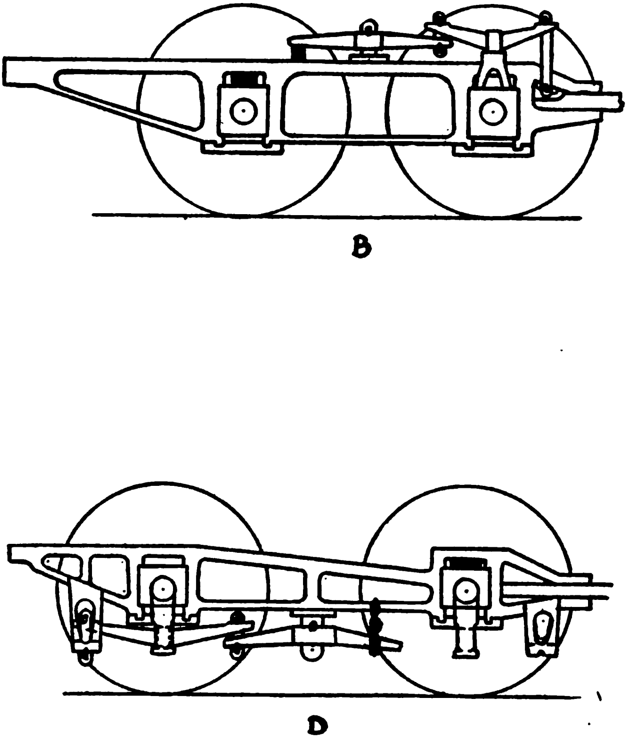


Fig. No. 121

BROKEN MAIN JOURNAL OVERHUNG TYPE

Fig. 122 shows the method of handling a broken main tire or journal on an overhung engine. Should the tire become broken it can be raised up as explained in Fig. 119, but in case of a broken main driving axle outside the box it must be jacked up and a block inserted as shown between the spring saddle and frame. A block must be placed between the pedestal brace and journal as shown. It will be necessary of course to remove the driving box cellar and place some oily waste or grease between the block and journal. Blocking between the spring and saddle may throw too much weight on the main frame, pulling the engine down too low; in such a case block over the back driver on the broken side to hold it up in position. Remove all rods except the main rod on the good side. Clamp the valve centered on the broken side and make the piston fast by use of a chain or blocking and place a collar on the good main pin. If necessary cut out the driver brake proceeding with the main wheel only for moving the engine. Should the tire only be broken proceed to suspend the driving wheel as described and proceed, provided the rods are uninjured.

Fig. 123 shows the same breakdown on an underhung engine; proceed the same as described in Fig. 122, but chain up the end of the equalizer as shown instead of blocking between the spring saddle and frame.

Fig. 124 (A) shows the method used for a broken equalizer on an overhung engine.

The broken parts are removed and the blocking in-

Fig. No. 122

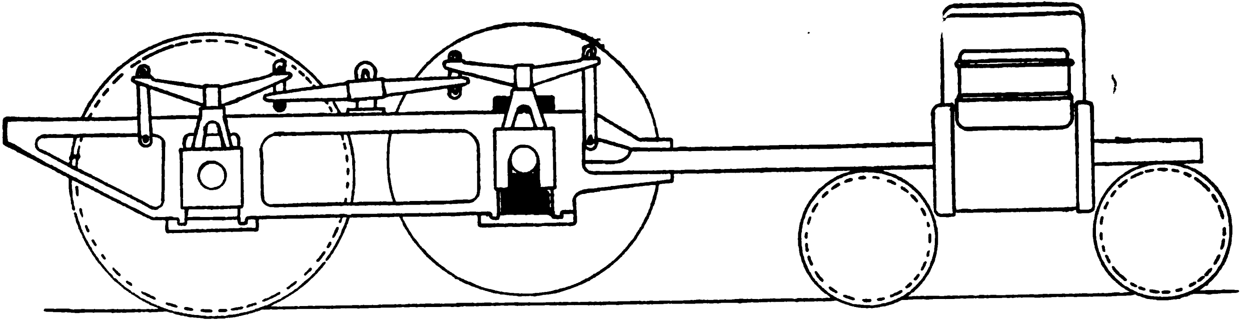
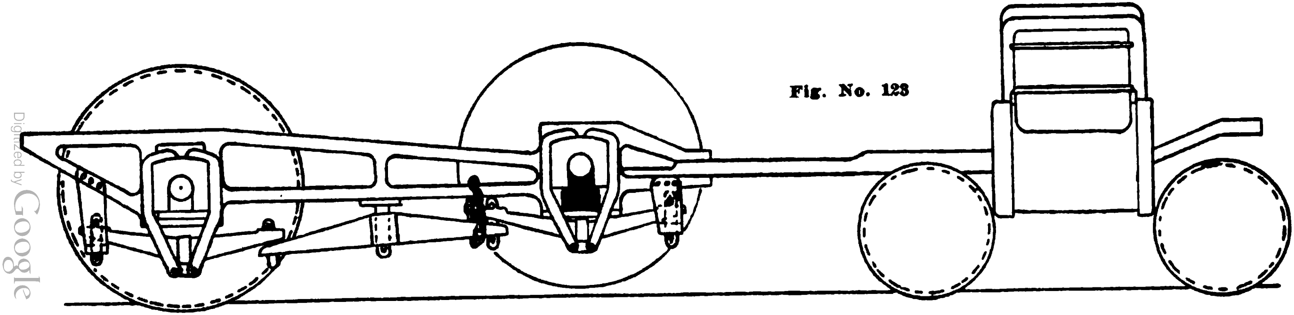


Fig. No. 123



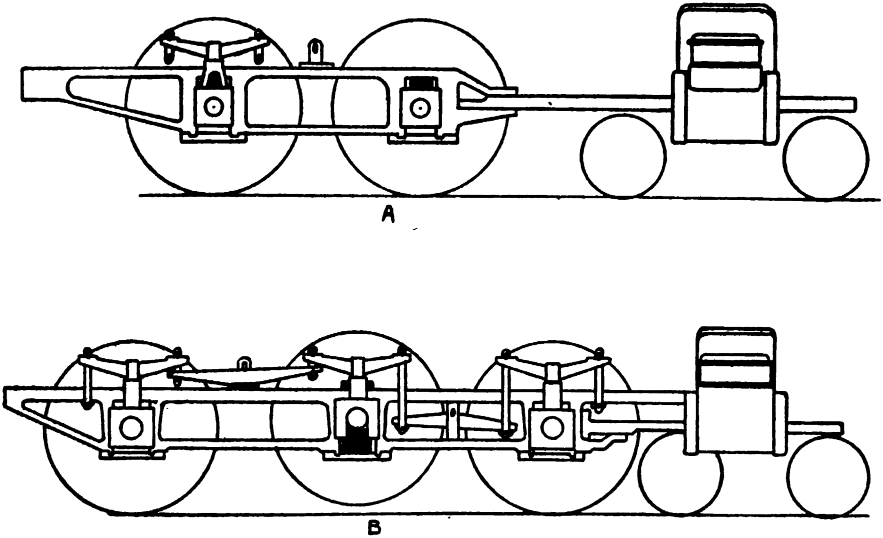


Fig. No. 124

serted over both driving boxes on the disabled side as shown.

Diagram B shows the method of handling a broken main tire on a ten wheel engine. In this case, should the tire fit the wheel tightly and the side rods be uninjured, the wheel can be raised up by means of a wedge already explained or by use of jacks. After getting the wheel up above normal position remove the oil celler and fit a block in its place as shown in the figure, the lower portion resting on the pedestal brace; the block should be well lubricated before placing it in finally.

While the engine is up in the position shown, a block should be inserted between the spring saddle as shown in the diagram. Should the engine settle badly when run off from the wedge, a block should be inserted over the back driving box and between the frame rail; this block should allow the other springs to take all the tension possible before any weight is placed on it. That is, the block when inserted should allow for about 2 inches settling of the engine before any load is taken on it; this will allow the other springs to take quite a little tension.

The driver brake should be cut out to prevent taking the tire off during an application of the brake.

The same method is applicable to an underhung engine except the ends of the equalizers should be chained to the frame rail next to the defective driving box to transfer the weight to the main frame and from the main frame to the driving springs, as explained before.

BROKEN PISTON OR PISTON ROD

This breakdown will generally take out the forward cylinder head. In such a case extreme care should be exercised to prevent getting the good side on the center, especially on a single track line where help cannot be furnishd quickly.

The best method to follow in such a case, is for example—watch the main pin on the right side and assuming the left piston rod be broken, just as soon as the right main pin comes to the quarter, apply the brake fully and reverse the lever giving the engine steam; this will give the effect of the brake and steam will be admitted to the opposite side of the piston, thus preventing it from reaching the dead center.

After the stop examine the broken parts and if the rod is all right disconnect the valve rod or radius bar, center the valve and go along.

Should the piston rod be broken so that a few inches must pass through the stuffing box remove the gland so there will be plenty of space for it to travel through without striking.

See also the method of disconnecting valve gears to describe further the method of handling the above accident.

BROKEN SIDE OR PARALLEL RODS

There has been considerable comment on just how these accidents should be handled on large power today. It is often possible to run an engine to the terminal with one section of side rods down and no bad results ensue, but, however, should the tire wear on the defective set of wheels be greater, the circumference of that wheel will be somewhat greater and when the wheel rotates on the rail it will tend to lead the others. The lead or lag of the wheels will continue until they arrive at some position where the side rod will tend to move them in opposite directions. For example—assume the main pin to be just below the center, the pin of the pair of wheels having the broken side rods, that is, the good side just above the center. Here we get a reverse movement and the result will be a pin broken off or a bent side rod and its attendant difficulties.

With large engines there is not a great deal of tendency to slip with all side rods down, provided the main driving wheels are blocked between the boxes and main frame, to place more weight on them, above that imposed by the spring arrangement.

BROKEN TRAILER SPRINGS OR HANGER

Atlantic Type—Remove the broken parts. First jack the side of the trailer equalizer up above normal position. Then chain the back end to the main frame, place a box over the trailer truck box between the box and frame.

Place the block over the trailer truck before you take out the jack.

Let the jack down. The weight will now be thrown on the block through the main frame, and the chain will take up the spring tension.

Pacific Type—The Pacific Type is more difficult to handle because of the radial trailing type of truck used and the leverage produced when one wheel is jacked up off from the rail; for example—When one side is jacked up the opposite side having greater weight on the journal will often raise the wheel clear of the rail and should the centering device be in poor condition the entire truck may be derailed.

The following seems to be the safest method. Jack the trailing truck clear up, chain the truck wheels through spokes to the main frame on both sides, placing the chains so they will not be excessive strain on any one spoke. Place blocks over the both back driving boxes, having about 2 inch clearance between them and the main frame. Next, slowly let down the jacks allowing the driving springs to take all the tension possible before the load is finally placed on the blocks over the back driving box. This method will place all the weight possible ahead on the driving springs so that the back driver will not carry too great a load. The engine must be run with great care over bridges because of the extra strain imposed on the driving wheels.

BROKEN MAIN FRAMES

This is an important subject today, notwithstanding the use of modern steel in locomotive frame construction, railroads continue to have many main frames break at some vital points.

In general the causes of frame breakage is traceable to loose pedestal or binder bolts and poor maintenance of the locomotive.

The excess strength of locomotive frames is often ten times the load the engine is capable of exerting through them, but, however, this strength is quickly broken down through the combination of strain and heavy vibrations.

What to do with a broken frame on the road is governed by the location of the break. For example—should the main frame break back of the main driver it can be run to the terminal light, but, however, should the break be ahead of the main driver, here we have a serious situation, as will be seen in the following examples.

It is possible on Mogul, ten wheel Micado and Pacific type engines, provided wedges and rods are in good condition, to run to the terminal with a broken frame ahead of the main driving wheels but having one pair of drivers ahead of the break. This will put the load on the parallel rod and no serious consequences result; of course the engine in this case should be run light.

It is generally recommended to remove both side

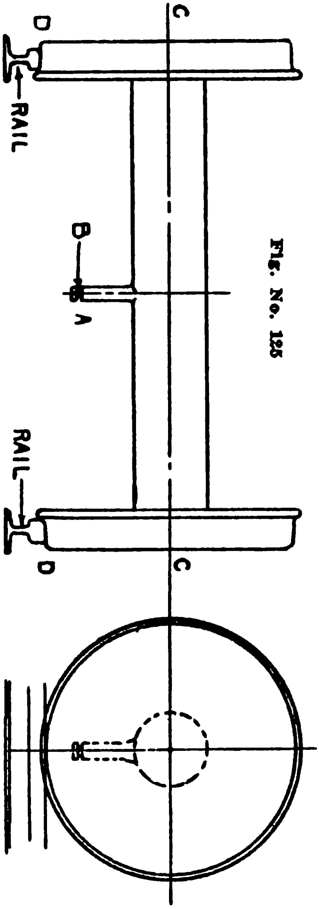


Fig. No. 125

or parallel rods behind the main driver when the brake is behind the main pair of wheels.

To show further what will happen to an engine with a broken main frame between the first pair of driving wheels and cylinder saddle. It will place considerable stress on the cylindrical portion of the boiler, as will be shown by referring to Fig. 125.

Here we have an ordinary pair of tender wheels with a short lever attached to the axle at A, with a groove B to which we will attach a rope. Let us assume a rope is attached to A at B and two men pull the rope. What will happen? The wheels will roll toward the men. Why? Because the lever A is less than the lever measured from the center of the wheels to the rail shown as the distance C to D.

Assume the same situation with the engine having a broken frame between the first pair of driving wheels and cylinder saddle. Assume also the engine is to move from the lower quarter ahead, steam will be admitted to the cylinder through the forward steam port, the pressure will act on the main pin in the same manner as given in the previous example. That is, the steam entering the cylinder would cause the wheel to revolve just the opposite direction in which it actually moves. Then how does the engine move in the forward direction? When steam is admitted to the forward port it pushes on the piston and against the cylinder head, but both in opposite directions; the piston has the leverage equal to one-half the stroke. For example—in Fig. 126 the length of the arm A and at the same time the cylinder head exerts its force through the main frame giving a greater lever, shown by the distance in Fig. 126 as C to D. The result then boils down to the fact that the main frame actually moves the driving wheels when standing on the lower quarter, and since this is true the broken main frame will cause most of this strain to be put through the boiler to the belly braces behind the broken section or through the guides, should the frame be broken between the guide blocks, and therefore serious consequences may result.

Fig. 126 will also explain the reason for placing the engine on the top quarter when locating a pound as

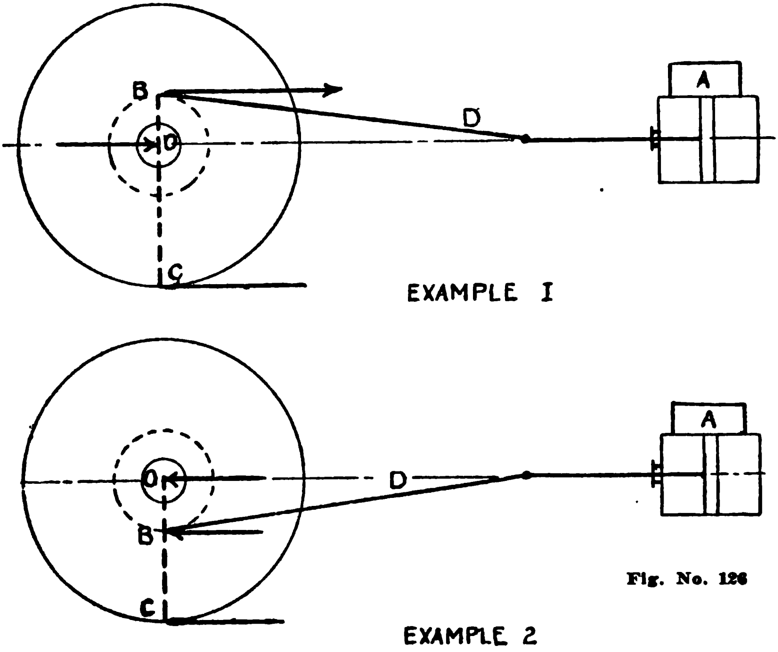


Fig. No. 126

already described; the leverage at the top quarter is the distonce B to C in example 1 and from B to C in example 2; it will be seen therefore the lever in example 1 greatly exceeds that in example 2.

The figure also shows where the greatest force comes on the driving box jaw when runnning ahead. For example—on the top quarter we have the leverage B to C example 1 and B to C in example 2; the lever in example 1 greatly exceeds that in 2, therefore the load on the forward driving box jaw will be much greater than that on the back side, the total load on the main rod and piston being the same when the engine takes steam at each end of the stroke.

HANDLING DEAD ENGINES

It is often convenient to place a dead engine in the house by use of air pressure. In doing this the following method should be adopted:

First see that the cylinder cocks and by-pass valves are closed, open the throttle, put the lever in the back gear, and have the engine towed ahead until you pump up 70 or 80 pounds of air, being particular to close the throttle when the engine is brought to a standstill. The air pressure obtained will be sufficient to place the engine on the turntable and back it into the engine house. Should it be a short track, it could be done by towing forward and back, closing throttle and changing the position of the reverse lever; for example—it must be kept opposite to the direction in which the engine is moving.

When this plan is used the cylinders function as an air pump and the boiler like that of a reservoir;

the air is drawn down through the exhaust pipe while the seam port registers with the exhaust. The piston moving opposite to the valve for a certain time will form a vacuum in the cylinder; the air will rush down through the exhaust base or pipe and as the piston reverses its movement the valve will close the connection between the steam and exhaust ports and later open up the steam port to the chest. The piston traveling back will compress the air contained in the cylinder, forcing it into the steam chest and boiler.

This plan is often used when engines are put into storage in order to drain the boilers and cylinder saddles of water. By removal of washout plugs an air pressure can be had to blow out any water accumulating in the steam passages or superheater units; for example—the air pressure passing from the cylinders will force the water into the boiler and thence out through the washout plug holes.

The air flowing down through the exhaust base will carry any water over into the cylinders that may be trapped in the exhaust passages of the cylinder saddle, and by opening the cylinder cocks the water can be let out.

COMPOUND LOCOMOTIVES

A compound locomotive is one that uses steam expansively more than once in its cylinders.

Generally compound engines have one high pressure cylinder, receiving its pressure directly from the boiler, and a low pressure cylinder, receiving the steam that is exhausted from the high pressure cylinder working the same through the low pressure cylinder.

A single expansion engine is one that uses high pressure steam from the boiler in both of its cylinders. An engine that is termed double expansion is one that steam is expanded first in the high pressure cylinder and then in the low pressure cylinder, generally called a compound.

A balanced compound engine is one having two high and two low pressure cylinders. The crank pins are connected up so they are equally spaced on the quarter. This type of engine is used largely on European railroads. Many of these locomotives are supplied with two valve gears to equalize the work in the low pressure cylinder.

The following figure will show the principle of the work done in compound cylinders by the pressure acting on them.

THE PRINCIPLE OF THE COMPOUND

Referring to Fig. 131 we have a high pressure cylinder 22 inches in diameter and a low pressure cylinder 35 inches in diameter, and the question before us is: why does the large cylinder do about the same amount of work as the smaller one with so much less pressure? The pressure on the pistons as well as that inside of the boiler is measured to the square inch; there are 380 square inches on the high pressure piston and 962 square inches on the low pressure piston. Assuming the high pressure piston is receiving steam from the boiler at 170 pounds, the force here would be the pressure multiplied by the square inches or 380 × 170 giving us 64,600 pounds, the total pressure acting on the piston. The pressure acting on the low pressure

PRINCIPLE OF THE COMPOUND

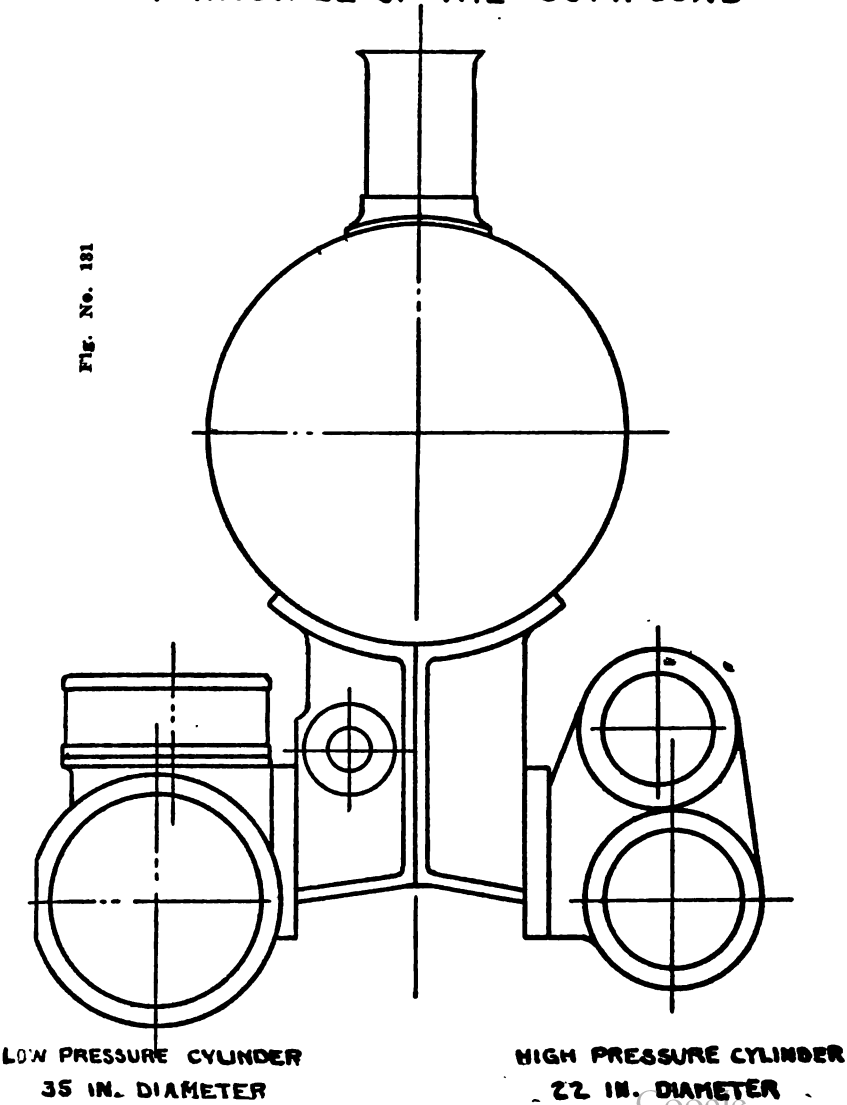


Fig. No. 181

piston is also acting as back pressure on the high pressure piston, so we must deduct that from the force tending to move the engine on that side.

Assume the pressure to equalize the work required on the low pressure side to be 48 pounds, then multiply the 48 pounds pressure by 380, the number of square inches on the high pressure piston, and subtract this sum from the 64,600 because this is back pressure.

Then $48 \times 380 = 18{,}240$; then $64{,}600 - 18{,}240 = 46{,}360$ pounds, the net force on the high pressure cylinder.

The low pressure cylinder had 962 square inches and our pressure against the piston being 48 pounds, multiplying these together we get 46,176 pounds. It will be seen there is but slight difference in the total force between the cylinders.

It must be remembered, however, these conditions do not exist during the entire stroke and are only used to show the relative work to be done by each piston.

The low pressure cylinder is proportioned to give about three times the area of the high pressure cylinder in order to equalize the work on the pistons.

An intercepting valve is used to run the engine simple in starting a train or in case of a break down, making it necessary to work the engine on the low pressure side.

When working simple the pressure entering the low pressure cylinder does not exceed one-half the boiler pressure carried, the reducing valve taking care of this.

THE ADVANTAGES OF THE COMPOUND

A saving in fuel consumption of 15 to 25 per cent. is available whether the engine is saturated or superheater, because the range of expansion can be divided between two cylinders instead of one and the same amount of work done with a smaller steam consumption.

The above is due to the range of temperature of the steam coming in contact with the cylinders will not be reduced and consequently the heat losses due to cylinder condensation, especially in the high pressure cylinder, will be less.

A much higher rate of expansion (the number of times the steam at cut off in the high pressure cylinder can be expanded) can be had than with a single expansion or simple engines.

Modern valve gears do not show any economy at shorter cut off than 30 to 35 per cent.; some recent tests even show that steam cut off at 45 per cent. of the stroke only expanded to ¾ of its volume at cut off when exhausted, and at 30 per cent. cut off expanded to twice its volume, this latter being the most economical cut off for modern engines. This expansion can be increased by use of a compound cylinder.

Tests show that it requires 24 pounds of water per hour per horsepower to supply a single expansion or simple engine with steam and but 18 pounds for the compound.

It is claimed that the compound gives more even traction, especially the four cylinder type.

A saving of 35 per cent. is available with a superheater over the saturated simple engine.

Some of the disadvantages of the compound are: Excessive maintenance cost especially in high speed type engines; it is also difficult to have the engine work freely on account of the steam being at low pressure and large valume to be handled through the low pressure exhaust ports passages and through the exhaust nozzle.

Compound engines therefore should be used on low speed trains only.

While the compound saves fuel while at work it will waste considerable, however, by pumping air through the stack while drifting. This will draw on the fire unless some type of efficient by pass valve is used.

The two principle systems of compounding are the Mellin and Simplex, the following will describe each.

THE AMERICAN ARTICULATED COMPOUND LOCOMOTIVE

An articulated compound locomotive is one having two sets of cylinders which drive separate and independent groups of wheels and one of which ordinarily uses exhaust steam from the other. Both sets of cylinders are supplied with steam from a single boiler.

The rear group of wheels is carried in frames rigidly attached to the boiler in the usual manner while the frames which carry the front group of wheels are not secured to the boiler, but support it by means of sliding bearings.

In addition to these advantages, due to its wheel arrangement, the articulated compound locomotive possesses all those derived from compounding the steam. Steam from the boiler is admitted to the first set or high pressure cylinders which ordinarily drive the rear group of wheels and, having done work in those cylinders, is then used over again in the second set or low pressure cylinders, which are connected to the front group of wheels. From the low pressure cylinders, the steam is exhausted to the atmosphere.

Connecting the high and low pressure cylinders, is a large pipe called the receiver, into which the steam from the high pressure cylinders exhausts when the locomotive is working compound. From the receiver the steam is admitted into the low pressure cylinders by their valves in the usual manner.

The low pressure cylinders have a larger piston area than the high pressure cylinders, the relative size of the two being such that, at the ordinary working cut-off, the steam at the lower pressure per square inch, acting against the larger piston area, exerts the same force as the higher pressure steam acting on the smaller area. Consequently, the stroke of the high and low pressure cylinders being the same, the two sets of cylinders ordinarily do practically equal amounts of work.

In the American Locomotive Company's system of compounding, the intercepting valve is so designed that when the engine is working simple the exhaust from the high pressure cylinder passes directly to the atmosphere and the valve cuts off communication between the receiver and the exhaust side of the high pressure pistons. This relieves them of all back pressure except that of the steam exhausting to the atmosphere. In addition, the low pressure pistons exert more power when working compound because the pressure of the live steam admitted to them, though reduced, is higher than the ordinary receiver pressure. This additional power added to that secured in the high-pressure cylinders from the reduction of the back pressure gives 20 per cent. total increase in power when working simple at slow speed.

OPERATING

Starting—Always open the cylinder cocks in starting.

Changing to Simple Working—Work the locomotive simple only when it cannot otherwise start the train or when the train is about to stall.

Never work the locomotive simple when it is running at a speed of over 3 or 4 miles an hour, as at such speed no increase in power will be obtained.

Drifting—When drifting, keep the reverse lever at ¾-stroke or more, as the locomotive will then drift freely.

The by-pass valves should be taken out and cleaned periodically to prevent them from getting gummed and sticking. When the locomotive is first put into service, these valves should be cleaned quite frequently for a few times to keep them free from the core sand, which is sure to work in.

Lubrication—Give the intercepting valve a liberal feed of oil for a minute before starting, and occasionally during long runs when the throttle is not shut off for a considerable period of time. Except for this, one drop of oil to the intercepting valve every four or five minutes is ample when running.

A list of the other parts of the American articulated compound locomotive which should be oiled and which are not found on the ordinary locomotive is given below, together with instructions as to the frequency with which they should be oiled.

Sliding boiler bearings on the front engine (before starting on a trip).

The ball joint in front of the high pressure cylinder (before starting on a trip).

The upper or rear ball joint of the exhaust pipe (before starting on a trip).

The lower or front ball joint of the exhaust pipe (before starting on a trip).

The bolt of the articulated connection between the two groups of wheels (before starting on a trip).

The ball bearings of the vertical suspension or "trim" bolts which connect the upper rails of the front frames with the lower rails of the rear frames (before starting on a trip).

The ball bearings of the floating columns (if applied) (before starting on a trip).

Testing for Blows—To test for blows in the valves or pistons, throw the emergency valve in the cab to the simple position, namely with the handle pointing to the rear. Spot the locomotive and test the same as a simple locomotive.

In Case of Accidents—If one or more of the cylinders may be disconnected and the locomotive run in on the remaining cylinders, simply throw the emergency operating valve into simple position. Disconnect and block the disabled cylinder or cylinders.

INTERCEPTING VALVE

Changing into simple working is effected by simply opening an operating valve in the cab which controls the emergency exhaust valve. The emergency operating valve is an ordinary angle valve located in a small steam pipe running to the emergency exhaust valve. It is only used if the train is about to stall; that is, in an emergency; or in case of an accident in which one or more of the cylinders can be disconnected and the locomotive run in on the remaining cylinders.

The intercepting valve is located in the saddle of the left high pressure cylinder, to the left of the vertical and above the horizontal centre line of the cylinders.

Fig. 132 is a reproduction of a working drawing of the intercepting valve assembled.

In this illustration, the valve is shown in two positions, representing the position the parts automatically assume when the locomotive is working compound, and their position when the locomotive is working simple.

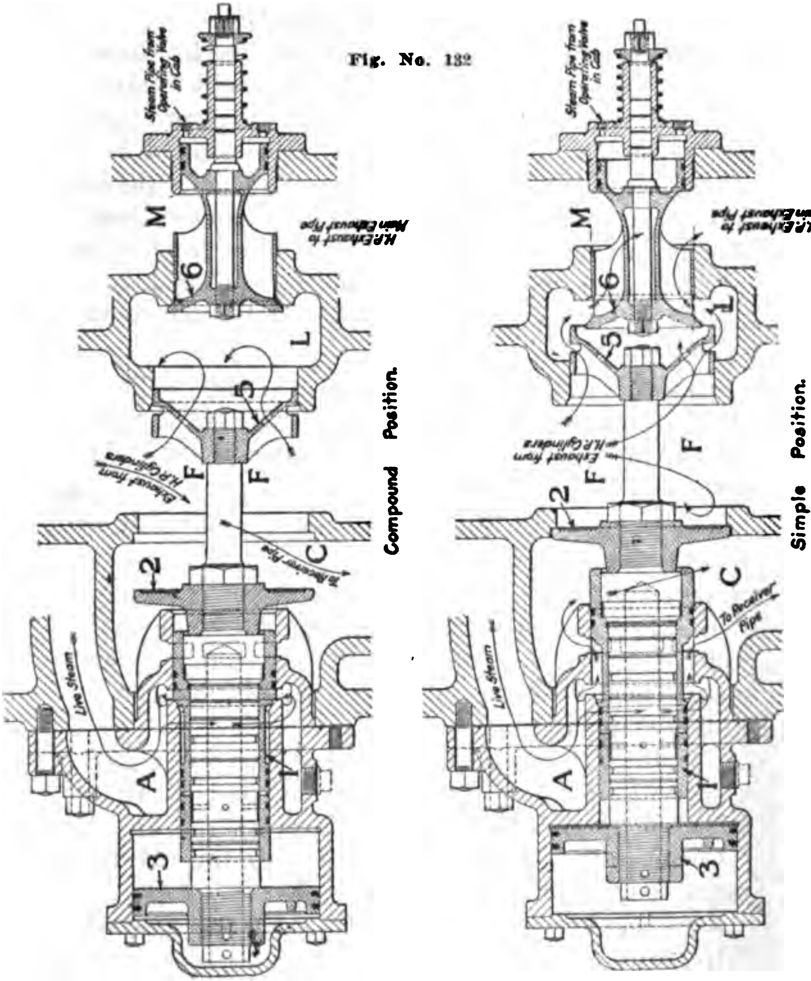
Chamber "C" opens directly into the receiver pipe. Communication between chambers "A" and "C" is established through the reducing valve (1).

Chamber "F" connects directly with the exhaust passages of the high pressure cylinders.

Between chambers "F" and "C" is the intercepting valve (2).

Chamber "F" is also connected with chamber "L" through the balancing piston (5) in which are a number of holes.

Fig. No. 132


Steam Pipe from Operating Valve in Cab
M
6
H.P. Exhaust to Main Exhaust Pipe
L
5
Exhaust from H.P. Cylinders
F
F
2
C
To Receiver Pipe
Live Steam
A
1
3

Compound Position.

Simple Position.

The emergency valve (6) establishes communication between chambers "L" and "M," the latter of which opens directly into the high pressure exhaust pipe, the small pipe which runs along the left side of the locomotive and connects to the main exhaust pipe.

Thus it will be seen that the reducing valve (1) controls the admission of the live steam from the boiler to the receiver pipe; the intercepting valve (2) opens or closes the receiver pipe to the exhaust from the high pressure cylinders; and the emergency valve (6) permits or prevents this exhaust from escaping through the main exhaust to the atmosphere.

When the locomotive is started in the ordinary way the pressure in chamber "A" opens the reducing valve (1), and this movement in turn closes the intercepting valve (2).

The reducing valve is so designed as to reduce the live steam entering the receiver to such a pressure that the low pressure cylinders will do the same amount of work as the high pressure cylinders.

Usually, this means a reduction to about 40 per cent. of boiler pressure. In the case of 200 pounds working pressure the live steam in the receiver would be reduced to 80 pounds.

If the pressure in the receiver rises above the amount to which the reducing valve (1) is designed to reduce it, the valve automatically closes and cuts off the admission of live steam to the receiver. It then remains closed until the movement of the low pressure pistons lowers the pressure in the receiver to the required amount when it again opens. The reducing valve can close without opening the intercepting valve (2); but these two valves cannot both be opened at the same time.

After one or two revolutions of the driving wheels, the steam exhausting from the high pressure cylinders into chamber "F" accumulates and its pressure rises sufficiently to open the intercepting valve (2) which in turn closes the reducing valve (1). The locomotive thus works compound; that is, the low pressure cylinders are supplied with steam by the exhaust from the high pressure cylinders. Fig. 132 also illustrates the intercepting mechanism in compound position.

The intercepting valve is usually so designed that when the pressure in chamber "F" has reached 30 per cent. of boiler pressure, it will open the valve against the steam in chamber "C" of 40 per cent. of boiler pressure, because the latter acts against a smaller area.

From the foregoing, it will be seen that, when operated in the usual way, the American articulated compound locomotive starts with live steam in all four cylinders and after a few revolutions of the driving wheels changes of itself into compound working.

If it is desired to prevent the locomotive from changing into compound after it is started, or to work it simple, and thus secure the maximum power of the locomotive at a critical point, it is only necessary for the engineer to open the emergency operating valve in the cab by turning it so that the handle points to the rear.

This opens the emergency valve (6) and allows the exhaust from the high pressure cylinders to escape to the stack. The reducing valve (1) is immediately opened, there being no resisting pressure in chamber "F," and closes the intercepting valve (2). Live steam is admitted to the receiver which at the same time is cut off from the exhaust side of the high pressure pistons and increased back pressure thus prevented.

The balancing piston (5) is employed in order that chamber "F" may be exhausted instantaneously with the opening of the emergency valve; with the result that the intercepting valve is closed and the reducing valve opened before or at the same moment that the receiver is actually exhausted. This prevents any drop of pressure in the low pressure steam chest during the change from compound to simple.

Fig. 132 shows the positions of the parts of the intercepting mechanism when the engine is working simple.

In the event that through neglect the reducing valve does stick, the difficulty can ordinarily be remedied by giving it a little extra feed of oil. If that fails, the cover of the dash-pot may be removed and the reducng valve moved in and out a few times with a bent piece of ¼-inch wire, after which it will probably clear itself when the throttle is opened.

BY-PASS VALVES.

These play an important part in the successful operation of the American articulated compound locomotive and although automatic in their operation they should be understood by the engineer.

They are applied to the low pressure cylinders and establish communication between the two ends of the cylinder when the locomotive is running with the throttle closed. This permits free circulation of air from one end of the cylinder to the other; and thus prevents any injurious effects from alternating vacuum and compression, which would otherwise occur from the pumping action of the large pistons when the locomotive is drifting.

If the locomotive is allowed to drift with the reverse lever hooked up, smoke-box gases may be sucked in by the cylinders and gum the by-pass valves. This possibility will be minimized if the reverse lever is kept at about ⅔ stroke.

Periodical cleaning of these valves is recommended.

VACUUM AND RELIEF VALVES

Vacuum valves are located in the high pressure steam chests or some other convenient place which is in communication with the steam chests. The function of these valves is to admit free air into the steam chests when the locomotive is drifting so as to avoid a vacuum and give a moderate flow of air through the cylinders.

The low pressure cylinders are equipped with combined vacuum and relief valves, which, in addition to having functions similar to the vacuum valves of the high pressure cylinders, also regulate the steam pressure in the low pressure steam chests. These relief valves are set at 45 per cent. of the boiler pressure and should be tested occasionally to see that they are properly set.

If they rise from their seats frequently when the locomotive is working compound, it may be due to a blow in either the valves or pistons of the high pressure cylinders, as such a blow would increase the pressure in the receiver, causing the relief valve to open. In such a case, the high pressure valves and pistons should be tested.

To test for blows, simply open the emergency operating valve in the cab; or in other words, change the locomotive into simple working. Spot the locomotive and proceed the same as with a simple engine.

IN CASE OF ACCIDENTS

In case of any accident in which one or more of the cylinders may be disconnected and the locomotive run in with the remaining cylinders active, simply throw the emergency operating valve in the cab into the simple position and proceed as with a simple locomotive. Disconnect and block the disabled cylinder or cylinders. This is the only rule to follow and the only one to be remembered, and covers all cases of accidents which do not entirely disable the locomotive.

"SIMPLEX" COMPOUND SYSTEM

The "Simplex" Intercepting valve is placed in a lagged and jacketed casing across the front face of the high pressure cylinder saddle. This casing connects with each of the high pressure exhaust passages in the cylinder saddles, and is provided at its lowest point with a socket for the reception of the receiver pipe ball joint, thus insuring perfect drainage. The casing is divided into four separate chambers, called respectively, beginning at the right-hand side of the engine (left side of drawing), live steam chamber, receiver chamber, high pressure exhaust passage, and separate exhaust chamber.

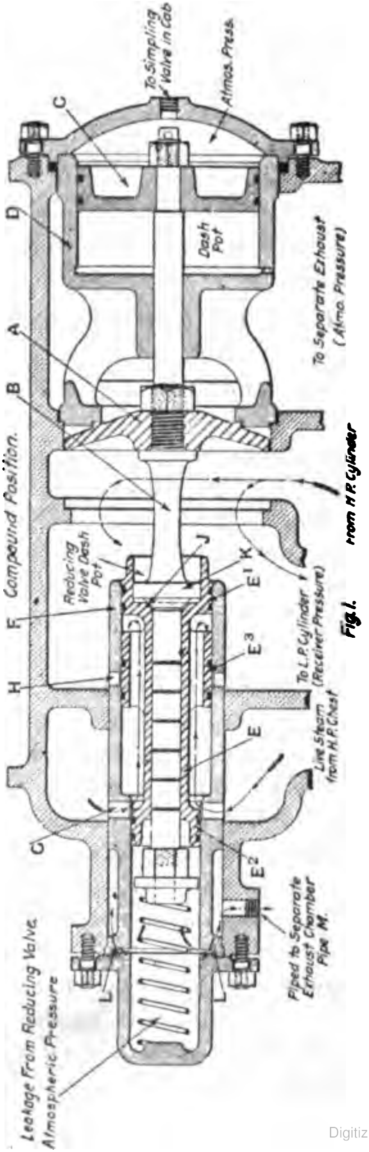

To Simpling Valve in Cab
Atmos. Press.
C
D
Dash Pot
A
B
Compound Position.
To Separate Exhaust (Atmo. Pressure)
from H.P. Cylinder
Reducing Valve Dash Pot
J
K
E^1
F
H
E^3
To L.P. Cylinder (Receiver Pressure)
Fig. I.
E
Live Steam from H.P. Chest
G
E^2
Piped to Separate Exhaust Chamber Pipe M.
L
Leakage From Reducing Valve Atmospheric Pressure

Fig. No. 138

Steam from the high pressure cylinders is controlled by the main valve, A, causing it to flow into the receiver chamber and thence to the low pressure cylinders when the engine is working compound, Fig. 133, and into the separate exhaust chamber when working simple.

Stem, B, of the intercepting valve, on which the main valve, A, is secured, is continued toward the left-hand side of the engine, and has fixed to this end a piston, C, which works in a cylinder, D. Live steam is admitted to the outer face of this piston when the simpling valve in the cab is placed in "simple" position, forcing the main valve into position. The inner face of this piston, by trapping air between it and the bottom of the cylinder, D, forms a dash-pot to prevent slamming.

On the continuation of the stem, B, toward the right side of the engine is a sliding reducing valve, E, which has a movement of one and a half inches on the stem, as well as a traverse of three inches with the main valve.

This valve has three functions:

First—To admit steam at a reduced pressure to the recveiver chamber when working simple.

Second—To force the main valve into compound position when pressure is released from the piston, C.

Third—To cut off the supply of live steam to the receiver when working compound.

The reducing valve works in a bushing, F, having a double concentric bore. The ports, G, admit live steam between the end pistons of the reducing valve at all times when throttle is open. The ports, H, admit steam at a reduced pressure to the receiver when working simple.

The first function of the reducing valve is accomplished as follows: Fig. 133, Piston, E^1, being larger than the piston, E^2, the live steam pressure admitted between these causes the valve to move in the direction of the large end and to assume the position shown. As soon as sufficient pressure is built up in the receiver this pressure reacts on the outer end of the piston, E^1, causing the valve to move in the opposite direction, cutting off the flow through the port, H. Thus a constant pressure, depending on the relative diameter of the pistons, E^1 and E^2, is maintained in the receiver when working simple.

A second function of the reducing valve, that of moving the main valve into compound position, is effected through this same tendency of the reducing valve to move in the direction of its large end, acting on the ground joint, J, on the reducing valve dash pot piston, K. This movement is aided in its early stages by the reducing valve pressure in the receiver acting on the main valve.

Fig. 135 shows the location.

A third duty of the reducing valve is performed by the intermediate piston, E^3, which closes the port, H, as soon as the stem, B, has moved sufficiently toward compound position, Fig. 133.

The small end of the reducing valve is vented to the atmosphere through the port, L, and include the pipe, M. Fig. 135, which communicates with the separate exhaust pipe. When working simple, should the high pressure engine slip, a considerable

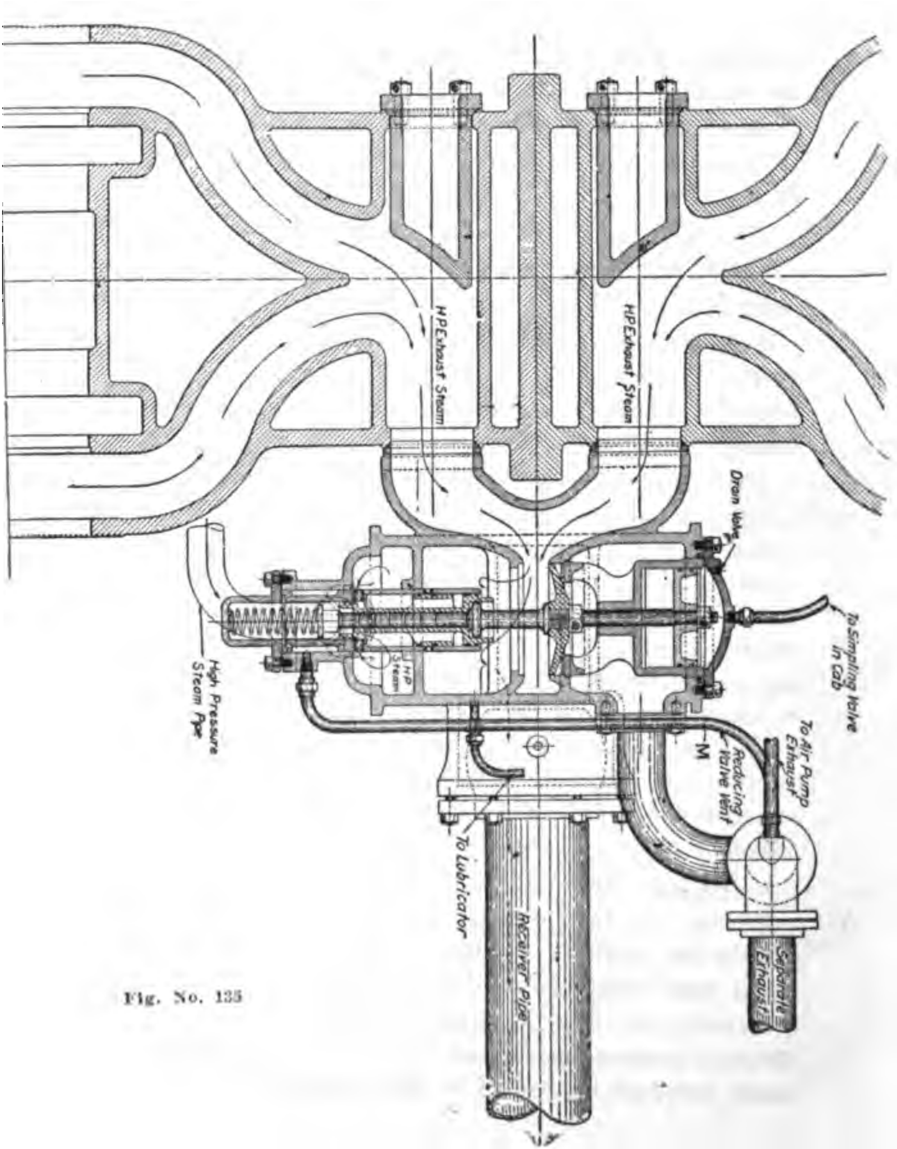

H.P. Exhaust Steam
H.P. Exhaust Steam
Drain Valve
To Simpling Valve in Cab
High Pressure Steam Pipe
H.P. Steam
To Air Pump Exhaust
Reducing Valve Vent
M
To Lubricator
Receiver Pipe
Separate Exhaust

Fig. No. 135

pressure is built up in the separate exhaust pipe. This, by reacting on the small end of the reducing valve, causes a high pressure to be temporarily admitted to the low pressure cylinders, thus maintaining the total draw bar pull as nearly constant as possible.

This entire mechanism, together with the operating cylinder, D, is removed as a whole by taking off the large head on the left side of engine.

Simpling Valve—This is a standard steam brake valve, stamped with the words "simple" and "compound" and placed conveniently to the engineer when sitting.

The separate exhaust pipe communicates with an annular removable nozzle surrounding the main exhaust nozzle. In this system the control of the power exerted by the high pressure cylinders when working simple is effected by the changing of this nozzle. The smaller the nozzle, the greater the back pressure acting on the high pressure pistons. This reacts on the reducing valve and adds power to the low pressure cylinders. Thus, a perfect balance of work in simple operation is effected. Back pressure in the separate exhaust chamber cannot unbalance the intercepting valve, or cause it to flutter.

Other features of this system are:

Placing the low pressure steam chest relief valves within the cylinder saddles, discharging to the exhaust pipe instead of to the atmosphere.

Venting the low pressure cylinder by-pass valves through a non-return check valve to the cylinder exhaust passages instead of to the atmosphere.

OPERATING THE SIMPLEX COMPOUND

Always start train with valve in simple position.

Change to compound as soon as train is under way.

Never simple after starting except to prevent stalling, or when drifting.

Very Important. In drifting down long grades, always place the simpling valve in simple position.

In case of break down, necessitating the disconnecting of either or both sides of high pressure or low pressure engine, the train may be brought in by placing the simpling valve in simple position.

Cut down lubricator feed marked "Intercepting Valve" as fine as possible, and feed only when working simple for considerable periods.

Oil operating piston through the cup on the simpling valve before starting on trip.

THE ALCO TRAILING TRUCK

Description

The essential features are as follows:

A built up truck frame which includes radius bar, boxes, and rear connection piece, the latter also serving as a fulcrum for the centering springs.

A floating yoke encircling the truck wheel and hinged at both ends to the main frame.

A floating spring seat hinged only at one end to the yoke, carrying the truck spring on its upper face, and its lower face sliding on the top of the truck box.

The usual wheels, axle, equalizing arrangement, and centering springs.

The truck frame combination presents no unusual features over previous trucks of this type as built by the American Locomotive Company. The radius bar may be either of bar iron for the lighter designs, or a heavier channel section of cast steel for heavy engines. This channel section of cast steel is also used when the trailer truck is arranged with truck brake hung from the truck frame.

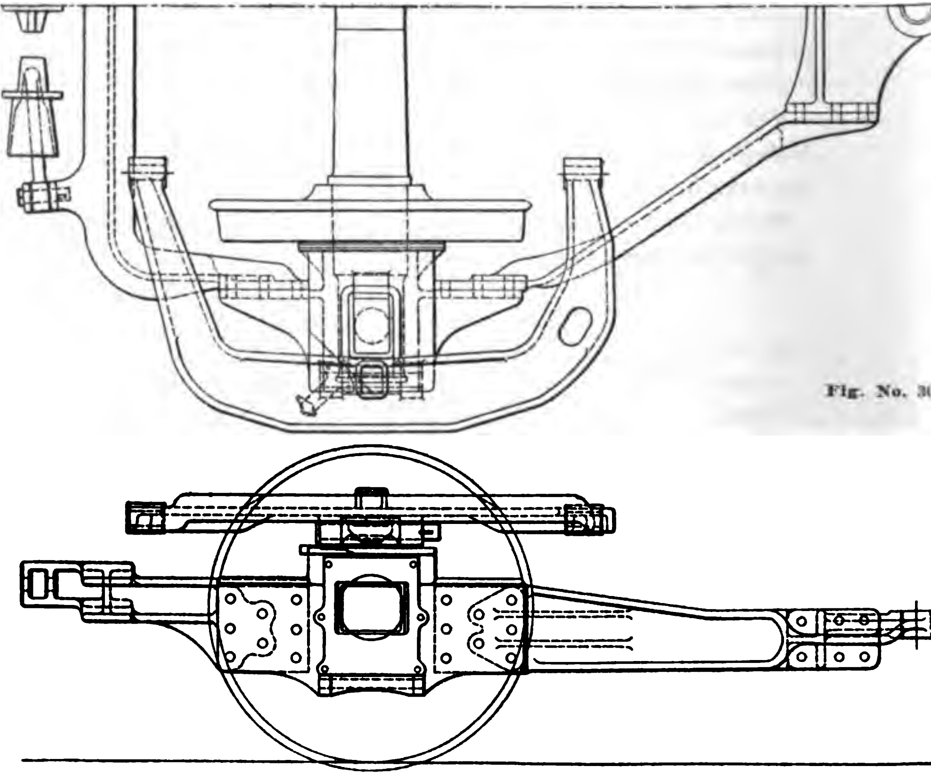


Fig. No. 3

The cast steel boxes are of the usual conventional design for outside bearing trailing trucks, having ample strength and lubricating facilities.

Brass liners are placed between the box and the wheel hub faces to take the thrust wear. A suitable sliding bearing surface is also provided on the top of the box for the spring seat with its loading.

The rear connecting piece is of cast steel and embodies integrally the centering spring fulcrums, and, when used, the brake hanger brackets.

The floating yoke is hinged at each end to the main frame. On the original design, this yoke directly carried the trailer truck spring seat. While this arrangement was perfectly satisfactory in so far as truck operation was concerned, it necessitated a greater overall height of truck than was desirable for ashpan clearance on large engines. On the new design the floating spring seat is hinged at one end to the floating yoke. This construction permits the lowest possible height of truck with consequent maximum room for ashpan as well as permitting perfect freedom for the spring and equalizer adjustment under load on uneven track.

The floating spring seat has an ample sized flat sliding bearing on the top of the box and is easily accessible for lubrication.

Wheels and axles are, of course, common to all outside-bearing trucks. The equalizing arrangement is simple and continuous. The rear end anchorage is formed by two wing castings, one on each side of the engine. Due to the wide spread of the transverse spring centres, these wing castings afford a very stable support to the rear end of the locomotive, and also prevent the rolling tendency of the engine at high speeds and on curves.

The centering springs, following the usual arrangement for outside bearing trucks built by the American Locomotive Company, act directly between the engine itself and the trailer truck frame. They are of sufficient length to allow for the maximum deflection for which the truck is designed, and being applied under an initial pressure, a positive action is secured under all conditions.

THE G. E. TURBO-GENERATOR HEADLIGHT SET

Operation

The steam is supplied to the machine through a ½-in. pipe which must be equipped with a globe valve within easy reach of the engineer or fireman; the steam being taken from the turret. It enters the machine at the bottom of the steam separator, up through the steam deflector (Ja) (see Figs. 300, 301) where, due to the abrupt deflection undergone by the steam, any water present in the steam is separated out and collects at the bottom of the separator, being drained off at the drain valve (Ea). The steam passes up through a perforated metal screen which is supported upon the separator plug and which covers the entire space at the top of the separator. This screen entirely protects the valve stem against any scale which might plug it. The dry steam then passes up through the center of the reducing valve stem (Ma) out through the holes (1) and (2) during which passage it undergoes a throttling action due to the tapered surface of the valve stem immediately below the holes (1). This tapered surface restricts the passage of the steam out through the holes (2) when the boiler pressure which is being applied at the bottom of the valve stem, forces the stem up against the pressure of the valve spring (Sa), the degree of this restriction being so arranged that a constant flow of steam is admitted to the nozzle chamber (3), throughout a range of from 125 to 225 lb. per square inch boiler pressure.

The steam after passing out of the holes (2), is led to the nozzle chamber (3), and thence through the nozzle (Eb) to the buckets of the turbine wheel (Va).

Immediately upon leaving the buckets, the steam is admitted to the exhaust passage and thence to the atmosphere.

The shape of this exhaust passage is such that the velocity of the steam as it enters and leaves the passage, sucks with it a considerable quantity of air which is admitted through a screen at the under side of the middle of the machine, thereby helping to keep down the temperature of the generator windings and also preventing any steam from leaking into the generator or condensing in the bearing housing.

The impinging of the steam, as it leaves the nozzle, against the buckets gives the required motion and velocity to the turbine wheel which in turn rotates the generator shaft (Cb).

The generator which is of the bi-polar compound-wound type, is composed of the armature, commutator and field frame. The armature is made up of laminated iron and wound with very simple form-wound coils, whose ends are connected to their respective commutator segments. The field frame carries two pole pieces, upon each of which are mounted the series (W) and shunt (Z) coils of the compound field winding, which are held securely in place by the coil field collars (X) and locking pins (Y).

The ends of the shunt windings are connected to the brush-holders (C) holding the brushes (E) which conduct the current from the commutator segments to the load circuit through the series windings of the compound field.

Sufficient power is supplied by the turbine wheel to drive the armature at a speed of about 3600, while it is supplying its full load rated current of 15.2 amps. at which speed the voltage of the generator is 33 volts.

In order to compensate for varying lamp loads down to no load an eddy current brake mechanism is provided. Mounted upon the wheel is a simple copper disk (Q). The edge of the disk rotates in the air gap of the brake pole piece or body (Db), and has a load induced in it depending upon the degree of magnetism of the brake pole piece (Db).

Upon the hub of this brake pole piece are mounted the shunt winding (Aa) and series winding (Ba) of the brake mechanism. The shunt coil is connected directly across the generator terminals while the series coil is connected in series with the load circuit. At no lamp load, the magnetizing effect of the shunt coil produces a sufficient drag upon the copper disk to maintain normal speed of the turbine wheel, while at full lamp load the series winding entirely neutralizes the magnetizing effect of the shunt coil and reduces the braking effect of the disk to zero. At any intermediate lamp load, the power from the turbine is absorbed partly by the lamp load and partly by the brake disk in the correct proportion to maintain constant speed and voltage.

Any overload or short circuit causes a magnetic drag upon the brake disk which immediately slows down the turbine wheel to a speed where no destructive valve of current can be supplied by the generator.

BRUSHES

The brushes, of which there are four, are held against the commutator by individual springs of the clock type, and are equipped with bead-insulated pig tails. An ample length of the brush is provided to give a life of about 5,000 running hours or over one year's service.

See that the brushes fit loosely in the brush-holder bodies and that the ends of the pig tails are secured firmly to the brush-holder body by the screws provided.

New brushes are ground to the correct radius to fit the commutator and should require very little if any grinding when renewing the brushes.

The grade of brush is known as Morganite CM-6.

BEARINGS

The bearings of which there are two are known as Hess-Bright No. 6305, although in emergency any make of No. 305 bearing may be used.

Their method of mounting is similar at each end of the shaft. They are held tightly in place against the steel spacing collars through the spreading of the slotted ends of the shaft by expansion plugs. In order to renew the bearings, first remove the bearing cap, then the expansion plug. The bearings may then be drawn from its housing by any square piece of stock which will fit snugly in between the inner and outer ball race.

In replacing a bearing, no difficulty will be experienced as all makes of No. 305 bearings are made to very close dimensions.

With reasonable attention bearings should last for at least 10,000 running hours or approximately two years.

LUBRICATION

Lubrication may be accomplished by the use of either oil or grease, a somewhat longer life of the bearings being obtained where oil is used.

The bearing housing is provided with a liberal oil well from which oil is carried to the bearings by an oil ring hung upon the steel spacing collar directly behind the ball bearing.

Oil may be admitted through the pipe plughole located at the side of the bearing housing.

Use any good grade of lubricating oil, although steam cylinder oil No. 600 W is generally more easily obtainable and more satisfactory.

Inspect the bearings at least every six months and wash out the bearing housing with kerosene to insure longest possible bearing life.

ADJUSTMENT

Due to the design of this machine only one part requires adjustment and it should never be required to be changed after leaving the factory, except where a higher or lower voltage is necessary.

To raise or lower the voltage, remove the bonnet (Ra) of the reducing valve by the two slotted screws holding it in position, and add to or remove some of the thin adjusting washes (Qa) located at the top of the valve stem (Ma) directly at the bottom of the spring (Sa). Washers of 0.010 in. thick will vary the voltage about 2 volts either way.

If voltage has been found to be too high, inspect the valve stem for dirt, etc., and after thoroughly cleaning with kerosene, replace with original number of washers. If the voltage is still high change the adjustment as described above.

Under no condition use any abrasive powder or paper on the valve stem.

If the voltage has been too low, remove the nuts holding down the separator cover and after lifting it off carefully, unscrew the nozzle locking nut (Ab) and withdraw the nozzle with the aid of a ½-in. metal rod threaded ½-in.—13 on one end. Carefully clean the bowl of the nozzle to remove any scale which might have collected and then replace carefully. The nozzle will only seat when it is replaced in the correct position.

If the voltage is still low adjust the valve stem with the washers as explained previously.

The normal pressure maintained by the reducing valve on the nozzle chamber is 100 lb. This may be tested by removing the ¼-in. pipe plug in the separator cover directly below the bonnet, and attaching a gauge.

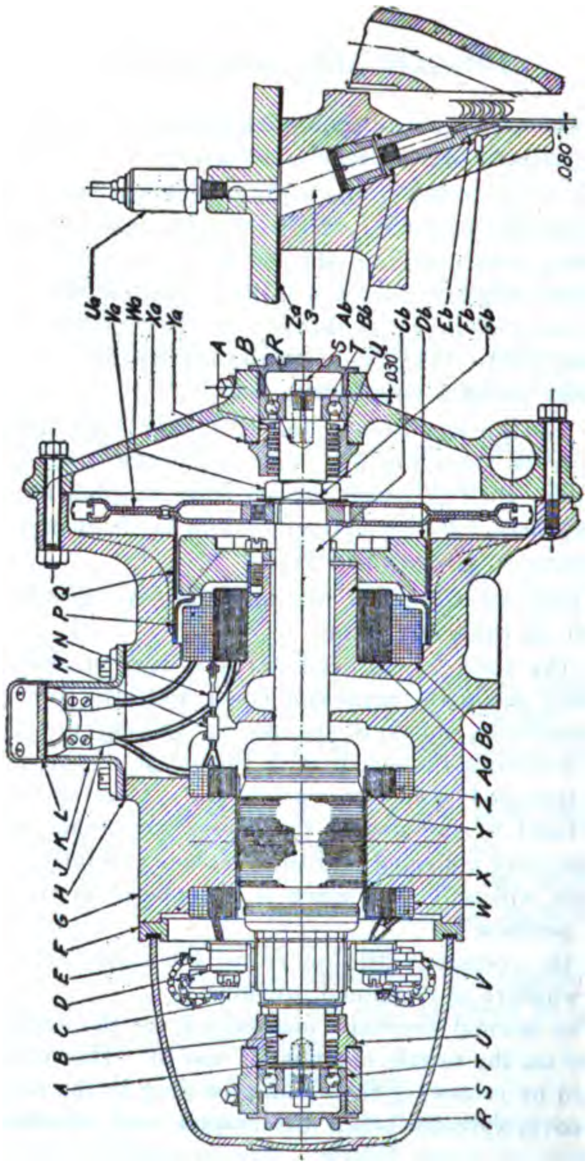

A
B
C
D
E
F
G
H
I
J
K
L
M
N
P
Q
R
S
T
U
V
W
X
Y
Z
Aa
Ba
Ua
Va
Wa
Xa
Ya
Za
3
Ab
Bb
Gb
Db
Eb
Fb
Gb
A
B
R
S
T
U
.030
.080"

Fig. No. 800

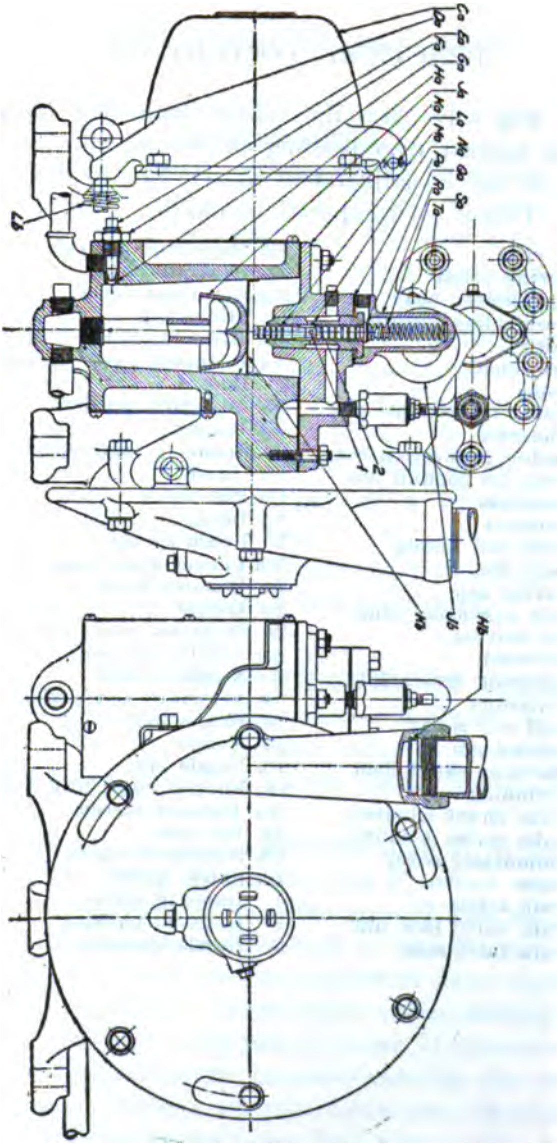


Fig. No. 801

The pop valve over the nozzle chamber is for protection against overspeeding of the machine in the event of any misadjustment or accident to the valve stem. This is set to operate at 120 lb.

A	Oil ring
B	Spacing collar
C	Brush-holder body
D	Brush-holder bushing
E	Brush
F	End shield
G	Frame
H	Gasket for conduct box
J	Connector
K	Conduit connection box
L	Cover for conduit box
M	Connector
N	Terminal
P	Brake coil casing
Q	Brake disk
R	Bearing cap
S	Shaft expansion plug
T	Ball bearing
U	Labyrinth
W	Generator series field winding
X	Field coil collar
Y	Locking pin
Z	Generator shunt field winding
Aa	Brake shunt winding
Ba	Brake series winding
Ca	Commutator cover
Da	Latch
Ea	Drain valve
Fa	Drain valve lock nut
Ga	Drain valve seat
Ha	Separator lagging
Ja	Separator plug
Ka	Separator cover
La	Hinge pin
Ma	Reducing valve stem
Na	Reducing valve bushing
Pa	Gasket
Qa	Adjusting washers
Ra	Bonnet
Sa	Reducing valve spring
Ta	Stud
Ua	Pop valve
Va	Bucket wheel
V	Brush spring
Wa	Bucket wheel nut
Xa	Exhaust head
Ya	Gasket
Za	Separator cover gasket
Ab	Nozzle lock nut
Bb	Nozzle gasket
Cb	Armature and shaft
Db	Brake body
Eb	Nozzle
Fb	Nozzle pin
Gb	Bucket wheel lock washer
Hb	Exhaust screen
Jb	Eye bolt
Kb	Separator screen
Lb	Latch spring
1	Holes in stem
2	Holes in bushing
3	Nozzle chamber

THE AIR BRAKE

Foreword—Starting the study of air brakes, the reader will find here a radical departure from existing literature on this subject. My idea is to bring home the principle of operation rather than to go into a tiresome detailed description of each device. This policy is adopted as a result of many years in actual contact with men who operate locomotives, and after a very comprehensive study in the direction of simplifying the subject. The following figures shown will reduce the principle to its lowest terms. Each and every piece of the apparatus is eliminated in order to make it crystal clear.

On account of the lack of space only the most common and important subjects will be covered.

THE PRINCIPLE OF THE TRIPLE VALVE

Let us assume we have as shown in Figure No. 138 a tank or reservoir A, a triple valve C, and a brake cylinder D, all connected by the pipes clearly shown in the figure.

Now assume we have a pressure of air at 70 pounds entering the valve or cut-out cock F, which we will assume in this case is open, the air will flow through the pipe K, through cut-out cock G, into the reservoir A; at the same time the same pressure flows through H to the chamber B of the triple valve, making the pressures equal on each side of piston H operating in chamber B, because the pressure entering the reservoir A passes through the pipe down into chamber C.

Now referring to the connection between the triple

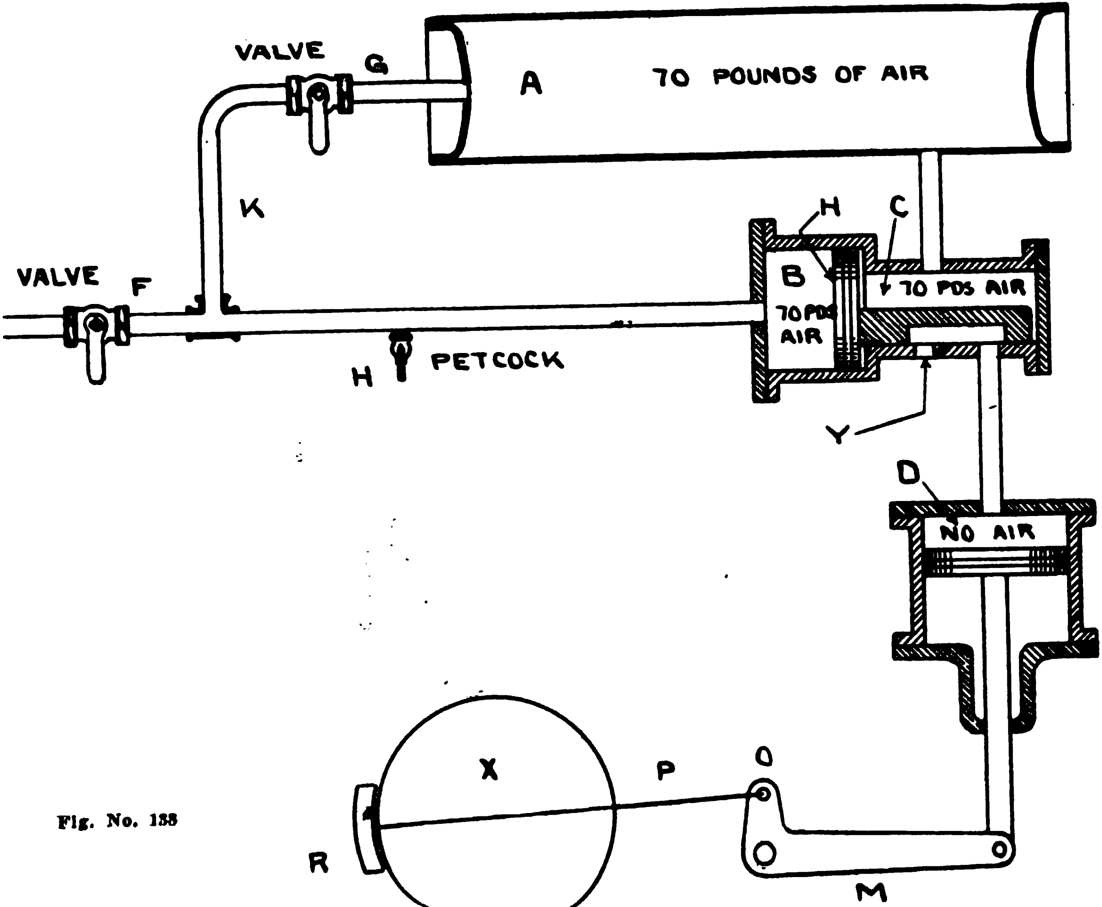
VALVE
G
A
70 POUNDS OF AIR
K
H
C
VALVE
F
B
70 PDS AIR
70 PDS AIR
PETCOCK
H
Y
D
NO AIR
X
P
O
R
M

Fig. No. 133

valve and the brake cylinder D, it will be seen that the cavity of the slide valve in this position connects the pipe leading to the brake cylinder D to the atmosphere through the port Y, that is, the slide valve straddles both passages as shown in the figure.

The brake cylinder D has a piston connected by push rod through the fulcrum M. pull rod P, to brake shoe R.

Let us assume we now have a pressure of 70 pounds in the reservoir on both sides of the piston H, and we shut cut-out cock or valves, F and G. Then open the pet-cock attached to pipe H, stop right here! What will happen? The pressure in H is connected to chamber B, so there will be a reduction made on the triple piston below that in chamber C. The pressure in chamber C will push the triple piston H over opening a direct passage from the reservoir A to the brake cylinder D, through the pipes shown in the figure. The pressure in brake cylinder pushes the piston and lever down, applying the brake shoe R to the wheel.

The action of the triple valve would be about the same if the reservoir A could be supplied with a constant pressure of water, and the cut-out cock moved to the other side of the T connection.

Figure 139 shows the action just explained. It will be noticed there has been a reduction made causing the piston to move over, pulling the slide valve so that the cavity does not straddle the exhaust port Y and the brake cylinder pipe, but shows that a direct flow of air exists between auxiliary reservoir A and brake cylinder D, through the connections to chamber C, in other words, they are connected together. Gen-

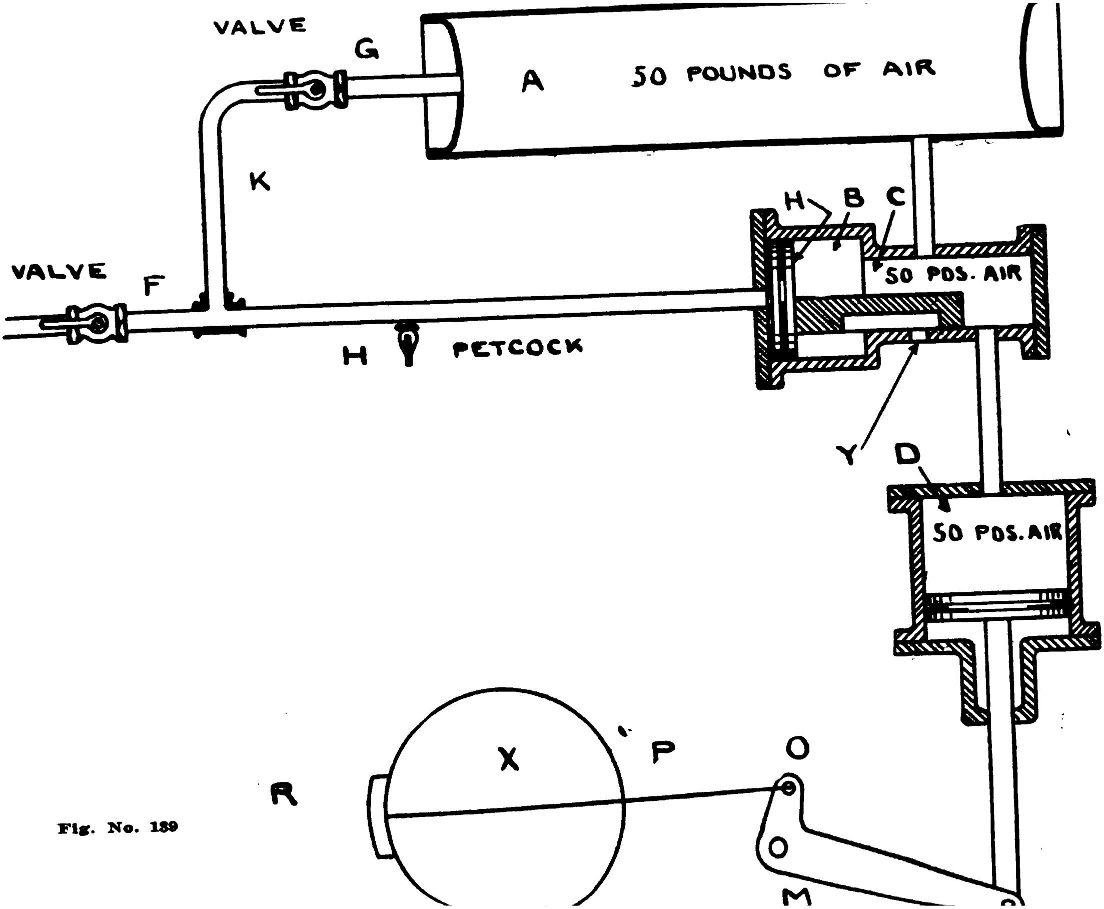

VALVE
G
A
50 POUNDS OF AIR
K
H
B
C
VALVE
F
50 POS. AIR
H
PETCOCK
Y
D
50 POS. AIR
X
P
O
R
M
O

Fig. No. 189

erally the pressure of equalization with 70 pound brake pipe pressure with eight inches piston travel in D is 50 pounds, as will be explained further on. It is strongly recommended that this principle be fully understood before proceeding further.

Referring to Fig. 140, let us assume that we do away with the pipe K and cut-out cock marked valve G in Fig. 139, and make a small groove at K instead. This will allow the air to pass by the piston to the auxiliary reservoir as shown, but much slower.

When a reduction is made by closing cut-out cock-marked valve F and pet cock in H opened a reluction in pressure will be made in the pipe and chamber B to which it is directly connected. The auxiliary reservoir pressure in chamber C will push the piston back by groove K, pulling the slide valve over, admitting air to the brake cylinder as before.

Since it takes quite a change in pressure on the piston to move the slide valve from release to application position, there would be a tendency for the brake to release when a service application is made and the valve moved to lap, that is, the auxiliary reservoir pressure would flow in too great a quantity to the brake cylinder. This would reduce the pressure in chamber C and the brake pipe pressure in chamber B would be higher and hence liable to move the piston over to release.

To overcome this situation a small graduating valve is used requiring but little change in pressure on either side of the piston to accomplish the proper opening and closing of the ports in service application. This will be explained further on.

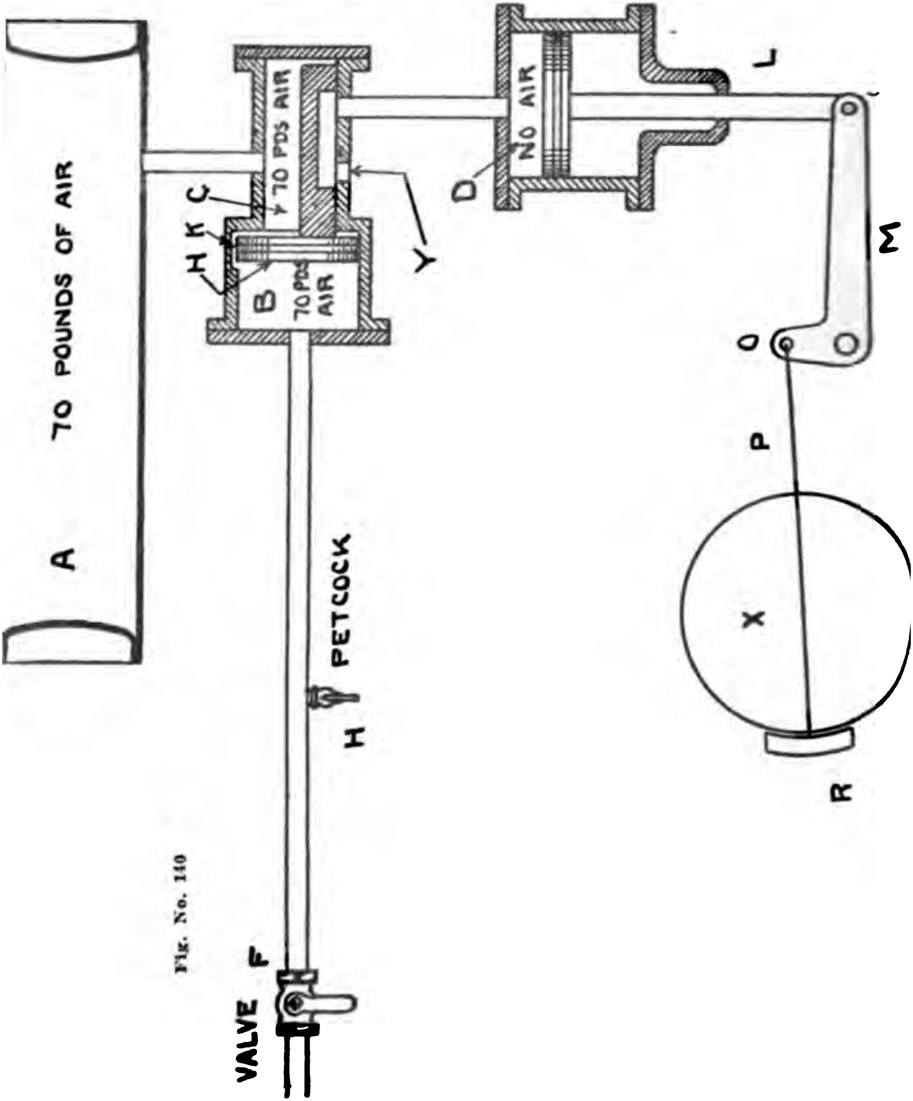

A
70 POUNDS OF AIR
70 PDS AIR
C
K
H
B
70 PDS AIR
Y
D
NO AIR
L
M
Q
P
X
R
PETCOCK
H
F
VALVE

Fig. No. 140

THE FEED GROOVE K

The first thing to be done is to obtain an air pressure in the auxiliary reservoir A. (See Fig. 140.) That is obtained by admitting air from the brake pipe to B, passing up behind the piston and through the small groove K in the piston bushing, which allows the air to flow slowly into the auxiliary. The rate of flow or the amount of air that can pass through this groove to the reservoir is on the average of one pound per second: that is, with a 70 pound brake pipe pressure it would take about 70 seconds to charge the reservoir A to 70 pounds pressure.

Now having firmly in mind the slowness in which the auxiliary reservoir charges, it will be seen that considerable time is necessary in order to charge a train up to the proper pressure before making the usual tests.

It will be seen also that any change of pressure on the brake pipe side of piston will affect it; for example, assume the brake pipe is charged to 70 pounds and the auxiliary is at the same pressure, and in one second's time you reduce the pressure on the brake pipe side (the plain side) to the extent of four pounds. At this instant there is a difference in pressure of about four pounds in favor of the auxiliary side, for the reason that the groove being so small will prevent the air from feeding back fast enough to keep the pressures equal on both sides of the piston. The result is the pressure on the auxiliary side having the above advantage pushed the triple piston over and carried the valve over allowing the air in the auxiliary to flow by it to the brake cylinder D, causing a pressure to act on the piston, push rod and through levers bringing the brake shoes against the wheels, as explained before.

Now, referring again to our figures of the principle of operation, let us see why the brake is automatic; assume that we have our auxiliary fully charged to 70 pounds and, of course, our brake pipe is 70 pounds, and for the purpose of explanation we will imagine an air hose has burst. Of course, the air hose is on the brake pipe side of the triple piston, and it is clear that pressure of 70 pounds will be at once reduced to nothing, leaving the auxiliary reservoir pressure of 70 pounds on the other side. This auxiliary pressure of 70 pounds cannot feed through the small feed groove fast enough to compensate the reduction now made so the result is the great pressure of the auxiliary reservoir will push the piston back, which will draw the slide valve over to a position allowing a communication from the auxiliary reservoir to the brake cylinder, resulting in an equalization of pressures between them.

As explained, it will also be seen that the triple piston in moving back will shut off the little feed groove (see Fig. 140), so that practically no air can feed past the piston. There is also another precaution taken to prevent leakage here, which will be explained later.

The action of our triple valve as explained in the above can be accomplished by separating of cars in the train, braking the train, or brake pipes, or in fact, anything that causes a reduction of pressure on the plain side of the triple piston.

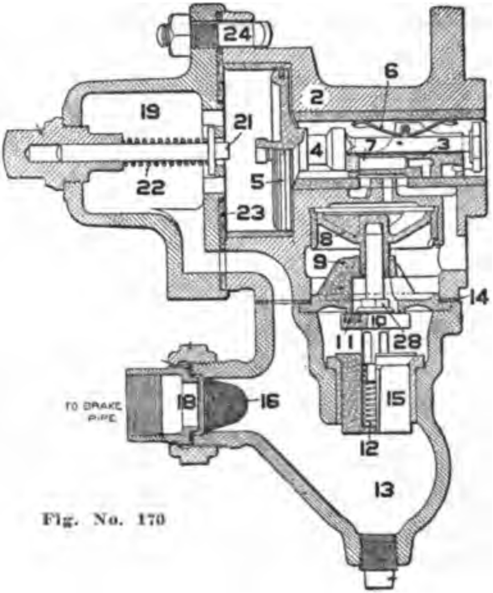


Fig. No. 170

Fig. 170 shows the quick action triple valve used largely today in passenger service. The principal working parts are: 3, Slide Valve; 4, Main Piston; 5, Main Piston Ring; 6, Slide Valve Spring; 7, Graduating Valve; 8, Emergency Piston; 9, Emergency Valve Seat; 10, Emergency Valve; 11, Rubber Seat; 12, Check Valve Spring; 15, Check Valve; 16, Strainer; Graduating Stem, 22, and the Graduating Spring, 23.

The quick-action triple valve is similar to the plain triple valve in principle, but has in addition the quick-action parts consisting of an emergency piston, emergency valve, and check valve. Besides these additional parts, the valve is arranged to be bolted to the pressure head of the brake cylinder in passenger equipments, or to the auxiliary reservoir in freight equipments, Fig. 164, thus making only one pipe connection necessary, the brake pipe branch. A strainer is provided at the branch pipe union connection to prevent the entrance of foreign matter to the valve.

THE AIR COMPRESSOR

Before starting a study of the Air Pump the reader's attention is directed to Fig. 143. The differential piston is often hard for a beginner to understand, but with a little study of the diagram it will clear up. It will be noticed that there is a cylinder of two sizes, a large piston B attached to a smaller piston by means of the rod C, each having a packing ring as shown. The chamber A in which the small piston moves has a cap with a hole in it at H. The larger piston has a cap into which the steam pipe is attached having the valve F and pet cock K.

The operation: Let us assume the pet cock is closed and valve F is open and steam is admitted through the steam pipe to the inside of the two pistons as shown, and since valve F is open it will also pass to the outside of the large piston B. Stop right here! What will happen? The pressure on each side of the piston B will be the same, and since the pressure is the same, it will be balanced and moved easily. The port H being nothing but a hole keeps the pressure from acting on the small piston from the outside; that is, it prevents the pressure from building up that might leak by the piston; now, since there is

PRINCIPLE OF DIFFERENTIAL PISTON AIR PUMP

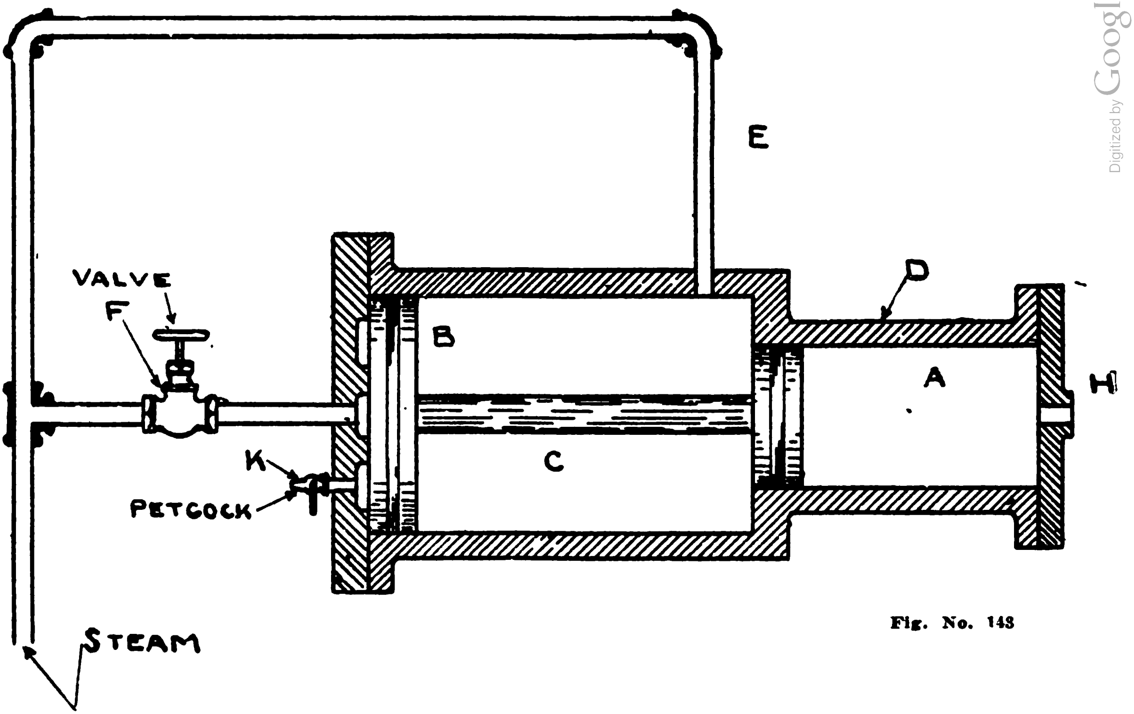


Fig. No. 143

equal pressure on the large piston and pressure on the inside of the small piston, the smaller will pull the larger back until it strikes the head.

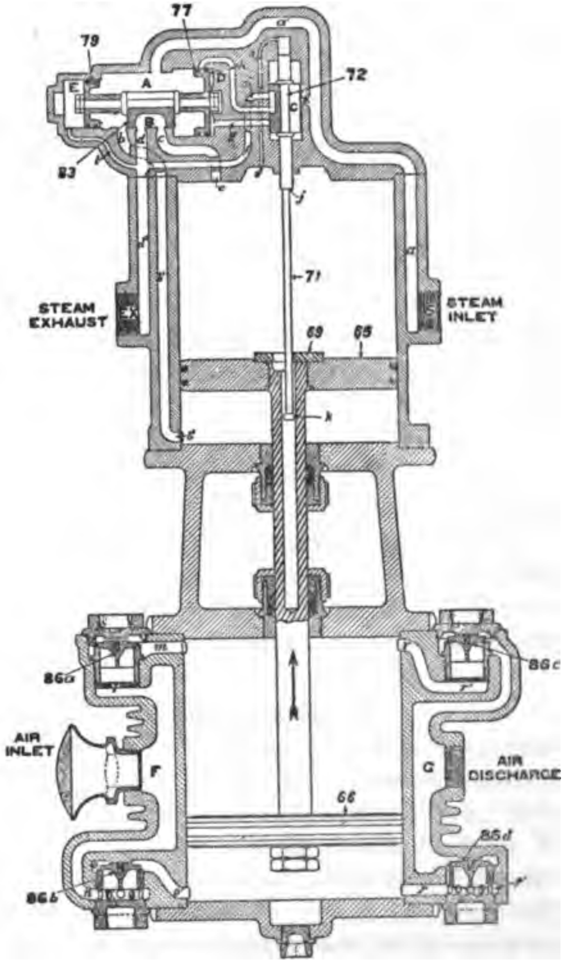
Now for the return; let us suppose we shut valve F and open pet cock K. What will happen? The pressure on the outside of the large piston will be released and since the pressure acting between both pistons is the same, the larger will have the greatest area and will pull the smaller back to the position as shown.

This is the only hard feature of the Air Pump to understand. The steam is admitted and exhausted from the outside of the large piston by means of a slide valve operated by the reversing valve rod, as will be seen in the following detailed description:

SINGLE AIR COMPRESSORS

Names of Working Parts

Steam Piston, 65.
Air Piston, 66.
Piston Rod.
Differential Piston, D.
Main Slide Valve, A.
Reversing Valve, 72.
Reversing Rod, 71.
Reversing Plate, 69.
Air Receiving Valves, 86A-86B.
Air Discharge Valves, 86C-86D.
Differential Piston Packing Rings, 77-79.



Diagrammatic View, Up Stroke

Fig. No. 144

The "standard" pumps are made in two sizes, each having steam and air cylinders of the same diameter, as follows:

9½-inch diameter by 10-inch stroke known as the 9½-inch pump.

11-inch diameter by 12-inch stroke known as the 11-inch pump.

The following descriptive matter applied to the 9½-inch and the 11-inch pump, the 9½ and 11-inch pumps being arranged to permit reversing the steam and exhaust connections, so that the pump can be located on either the right or left side of the locomotive and the piping arranged accordingly.

THE OPERATION

Sectional views of the steam and air cylinders and valve mechanism are shown . Figs. 144 and 145 are diagrammatic illustrations arranged to show the connections of all the ports and passages in a clearer manner than actual construction of the parts permit.

STEAM END

Referring to Figs. 144 and 145, steam enters at the connection marked, and flows through the passageway *a*, a^2, to the chamber *A*, above the main valve 83 and between the pistons 77 and 79, and through passage *c* to chamber *C* in which is the reversing valve 72. The intake and exhaust of steam to and from the steam cylinder is cotrolled by the main valve 83, which is a "D" type of slide valve. This valve is operated by the pistons 77 and 79, which are of unequal diameters and connected by stem 81.

The movement of these two pistons and the main valve is controlled by reversing valve 72, which is operated by the main steam piston 65, by means of the reversing rod 71, and reversing plate 69. The function of reversing valve 72 is to alternately admit steam to or discharge it from chamber *D*, at the right of piston 77, thus alternately balancing or unbalancing this piston. The reversing valve is operated by reversing rod 71. This rod is alternately moved up and down by reversing plate 69, which engages reversing shoulder *j*, Fig. 144, on the upward stroke of the steam piston, and button *k*, at the end of the rod, on a downward stroke.

Chambers *A* and *C* are always in communication with each other and the steam inlet through port e, e^1, as shown in the cuts, hence live steam is always present in these chambers. Chamber *E*, at the left of small piston 79 is always open to the exhaust passage *d*, through the ports t and t^1, in the main valve bushing. Exhaust steam, at about atmospheric pressure, is therefore always present in chamber *E*.

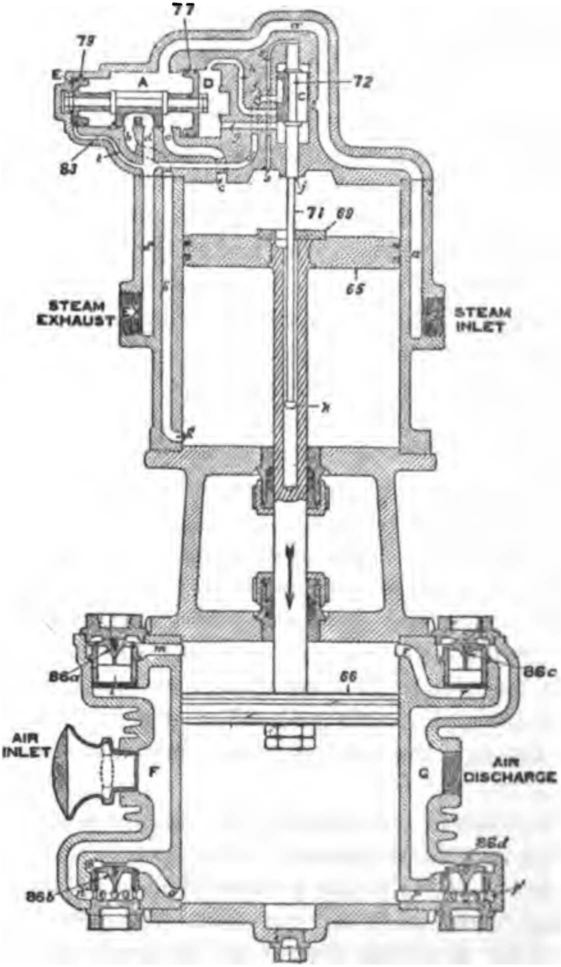
A balancing port, *s*, Figs. 144 and 145, runs diagonally to the right in the reversing valve cap nut, and connects with a groove along the outside of the reversing valve bush, which opens into the upper end of the cylinder through a small port in the head. The purpose of this balancing port is to insure the same pressure above and below the reversing rod, whether there is live steam or exhaust steam in the upper end of the cylinder, thus balancing the reversing rod so far as steam pressure is concerned.

When reversing slide valve 72 is in its lower position, as shown, connects (through ports h^1, h, reversing valve exhaust cavity H, and ports f and f^1) with main exhaust passage d, d^1, d^2, hence there is only atmospheric pressure at the right of piston 77.

As Chamber E, at the left of piston 79, and Chamber D, at the right of piston 77, are then both connected to the exhaust, the pressure of the steam in Chamber A has driven the larger piston 77, to the right, and this caused the smaller piston 79, and main valve 83, to move to the position shown, the main valve 83 thus admitting steam below piston 65, through port b, b^1, b^2. Piston 65 is therefore driven upward, and the steam above piston 65 passes through port c^1, c, exhaust cavity D of main valve 83, port d, and passage d^1, d^2, to connection Ex, at which point it is discharged through the exhaust pipe into the atmosphere.

When piston 65 reaches the upper end of its stroke, the reversing plate 69 strikes shoulder j on rod 71, thus moving rod 71 and reversing slide valve 72 upward to uncover port G, Fig. 145. Steam from Chamber C then enters Chamber D through the port g, and port g^1 in the bushing. The steam pressure upon both sides of piston 77 are thus equal or balanced. On piston 79, however, the conditions are different. Chamber E is always open to the exhaust, piston 77 is now balanced, the steam pressure in chamber A forces piston 79 to the left, drawing with it piston 77 and main valve 83, to position shown in Fig. 145.

With main valve 83 in this position, steam is admitted from chamber A, through port c, c^1, above piston 65 forcing it down; at the same time the steam



Diagrammatic View, Down Stroke

Fig. No. 145

below this piston is exhausted to the atmosphere through port b^2, b^1, b, exhaust cavity B in the main valve, port d^2, d^1, d, and the exhaust pipe connected at *Ex.*

When piston 65 reaches the lower end of its stroke, reversing plate 69 engages reversing button *k*, and draws rod 71 and reversing valve 72 down to the positions shown in Figs. 144 and 145, and one complete double stroke of the steam end of the compressor has been described.

Air End. The movement of steam piston 65 is imparted to air piston 66 by means of the piston rod. As the air piston 66 is raised, the air above it is compressed, and air from the atmosphere is drawn in beneath it; the reverse is true in the downward stroke.

On the upward stroke of piston 66, the air being compressed above it is prevented from discharging back into the atmosphere by upper inlet valve 86a. As soon as the pressure in ports r, r^1, below upper discharge valve 86c becomes greater than the main reservoir pressure above it, the discharge valve 86c is lifted from its seat. The air then flows past this valve down through chamber *G*, out at the "Air Discharge" and through the discharge pipe into the main reservoir.

The upward movement of the air piston produces a partial suction or vacuum in the portion of the cylinder below it. The air pressure below piston 66 and on top of the lower left-hand inlet valve 86b becomes, therefore, less than that of the atmosphere in port *n* underneath this valve. Atmospheric pressure therefore raises valve 86b from its seat, and atmospheric air is drawn through strainer 106, at the "Air Inlet," into chamber *F*, and port *n*, below the inlet valve 86b, thence past that valve and through ports *o* and o^1 into the lower end of the air cylinder, filling same. Air cannot enter this part of the cylinder by flowing back from the reservoir through passages *D* and *G* and lower discharge valve 86d, since this valve is held to its seat by the main reservoir pressure above it. The lower inlet valve 86b seats by its own weight as soon as the up stroke of the air piston 66 is completed.

On the downward stroke of the compressor, the effect just described is reversed, the air below piston 66 being compressed and forced out through ports *p* and p^1, past lower discharge valve 86d and through chamber *G* and the air discharge pipe into the main reservoir. At the same time air is being drawn in from the atmosphere through the "Air Inlet" through chamber *F* and port l^1, upper inlet valve 86a and discharges the air compressed on the lower end of the cylinder through valve 86d as described.

STARTING AND RUNNING

The drain cocks are located at the lowest part of the steam passages *a* and b^2, as shown for draining the water caused by condensation after the pump stops. Always leave these cocks open if the pump stands idle for any length of time. These cocks have union fittings so that drain pipes may be connected to them if desired.

In starting a pump, always run it slowly until it becomes warm and permit the condensed steam to escape through the drain cocks and the exhaust, until sufficient pressure is accumulated in the main reservoir (25 to 30 lbs.) to provide an air cushion. Then close the drain cocks and open the steam (throttle) valve sufficiently to run the pump at the normal speed, but no faster than is necessary to do the work required. Never allow the pump to run at excessive speeds. The pump governor set at the air pressure desired, automatically controls the starting and stopping of the pump.

LUBRICATION—STEAM CYLINDER

The steam cylinder lubricator should not be allowed to operate until all condensation has escaped from the pump and the drain cocks have been closed. Then start the lubricator to feed ten or fifteen drops of oil as rapidly as possible, and then regulate the feed to about one or two drops per minute for one pump. No exact quantity can be specified, as the amount of lubrication necessary depends upon the work the pump has to do, quality of steam, condition of pump, etc. Keep the lubricator feeding while pump is running.

LUBRICATION—AIR CYLINDER

To oil the air cylinder open its oil cock and blow out all dirt; then close and fill the cup with valve oil, and on a down stroke of the piston open the cup to permit the oil to be drawn into the air cylinder, but close the cup before the up stroke begins. This is easily done when the speed is moderate and air pressure low. Use valve oil only for the air cylinder. A lighter oil will not last and is dangerous. A heavier oil soon clogs and restricts the air passages, causing the pump to overheat and compress air slowly; valve oil gives the best results. Judgment must determine the amount of oil to use for both air and steam cylinders, remembering that the lack of a little oil when needed may cause many dollars' worth of damage to the pump.

A Swab, well oiled, is essential, on the piston rod.

Many railroads now consider it necessary to use Sight Feed Lubricator Fittings, located in the cab, and connected in piping leading from the oil well of the locomotive cylinder lubricator to the air pump cylinder.

AIR VALVES AND STRAINER

Any steam leakage that can reach the Air Inlet of the pump should be promptly stopped, as this increases the danger of water getting into the brake pipe.

Keep the suction strainer clean at all times. This is important, as even a slightly clogged strainer will greatly reduce the capacity of the pump if running fast. An almost or completely obstructed strainer, as by accumulated frost, aggravated by rising steam, will increase pump speed, and is also indicated by not being able to raise or maintain the desired pressure.

To insure good operation, thoroughly clean the air cylinder and its passages at least three or four times a year, by circulating through them a hot solution of lye or potash. Always follow this with sufficient clean, hot water to thoroughly rinse out the cylinder and passages, after which give a liberal supply of valve oil to the air cylinder. Suitable tanks and connections for performing this operation can easily be arranged in portable form. Never put kerosene oil in any air cylinder to clean it.

THE NEW YORK DUPLEX PUMP

Before the pump has been started, both pistons will naturally be at the bottom of the cylinders, due to their own weight, or, if not completely down, will at least have dropped enough to permit the piston valves to fall to the bottom of the steam chests.

Assuming for convenience of explanation that both pistons are down, when the pump throttle is opened, live steam flows into both steam chests B, and is always present in them when the pump is taking steam. In this instance only, steam is admitted to both cylinders at once, through port g to the upper side of piston H, which being at the bottom is merely held in that position, and through port o, to the under side of piston T (Fig. 145A). Piston T now moves upward and in doing so forces the air that is above the piston in low pressure cylinder D, through intermediate valve K, into the high pressure cylinder F. At the same time, the low pressure piston tends to create under it a vacuum, which is filled with air at atmospheric pressure through the air inlet at the right, and receiving valve W. Just before piston T reaches the end of its upward stroke, the tappet plate Q engages the button on the end of the valve stem P, which moves the piston valve C to its highest position, allowing the steam above piston H to pass through

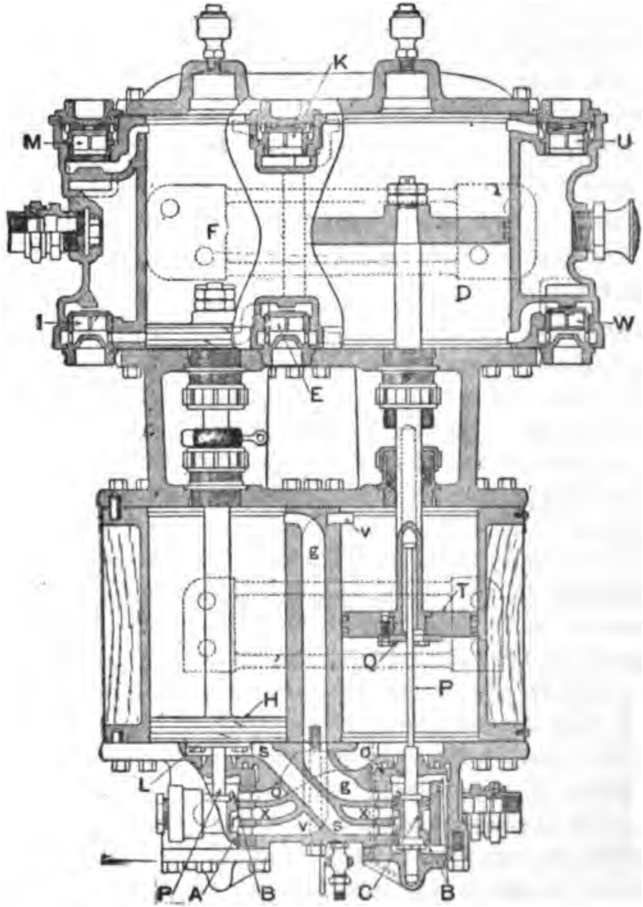


Fig. No. 145A

ports g, annular cavity r, in piston valve C, and the exhaust X, to the atmosphere, and live steam through port s, to the under side of piston H. As piston H moves upward, the high pressure piston in cylinder F forces the air above it, which may be said to be under the first stage of compression, through discharge valve M, to the main reservoir, while its upward movement tends to create a vacuum under it in the high pressure cylinder F, which is filled with air at atmospheric pressure through the air inlet, lower receiving valve W, low pressure air cylinder D and lower intermediate valve E.

Just before piston H completes its upward stroke, tappet plate L engages with the button on the valve stem, raising it with the piston valve A, exhausting the steam under piston T, through port o, cavity r, in piston valve A and the exhaust X to the atmosphere, and admitting steam through ports v to the upper side of piston T, moving it downward. During the downward movement of piston T, the low pressure piston in cylinder D forces the air under it which was taken in on its upward stroke, through the intermediate valve E to the underside of the piston in high pressure cylinder F, and at the same time cylinder D is filled with air at atmospheric pressure through the air inlet and upper receiving valve U. Just before the piston T completes its downward stroke, the tappet plate Q, coming in contact with the lower tappet or shoulder on the valve stem P, moves the piston valve C to its lowest position, allowing the steam under the piston H to exhaust to the atmosphere through port s, cavity r in piston valve C and the exhaust X, and admitting live steam to the upper side of piston H, through ports g, moving it downward. As piston H moves downward, the high pressure piston forces the air under it through the lower discharge valve I into the main reservoir, while the cylinder is filled above with air at atmospheric pressure through the air inlet, upper receiving valve U, low pressure air cylinder D, and upper intermediate valve K.

The completion of this stroke completes one cycle of the pump. The movements described are repeated through each succeeding cycle.

Before starting a pump, open the drain cocks in the steam and exhaust passages. Open the steam valve slightly at first, and run the pump very slowly until all the condensation has been worked out of the steam cylinders. Then the steam valve may be opened a little more, but the pump should be run slowly until a pressure of 50 or 60 pounds has been accumulated in the main reservoir. It should be run just fast enough to promptly restore the pressure in brake system, but never raced.

The steam cylinders should receive a constant supply of oil from the lubricator (about one drop a minute), and it is necessary to keep all joints between the lubricator and pump perfectly tight, so that no oil will be wasted. Oil can leak away at the steam joints, where there is little or no indication of steam leakage.

The piston rods should be kept well packed, and good, clean swabs well oiled should be maintained on them.

THE AUTOMATIC OIL CUP

The principle of operation of the automatic oil cup is as follows:

As the air piston makes its upstroke, compressed air is driven upward through the passage drilled through the centre post of the body of the oil cup, next passes downward inside the extended sleeve of the cap nut, and then through the regulating ports drilled in this sleeve, to the surface of the oil in the reservoir, on which it creates pressure. As the air piston makes its down-stroke, a vacuum is formed in the passage in the centre post, and also inside the extended sleeve of the cap nut which envelops the centre post, and the air pressure on the surface of the oil, forces the oil to the inside of the sleeve, and a small portion of it is drawn into the air cylinder through the hole in the plug, OC 32, which is pressed into the centre post.

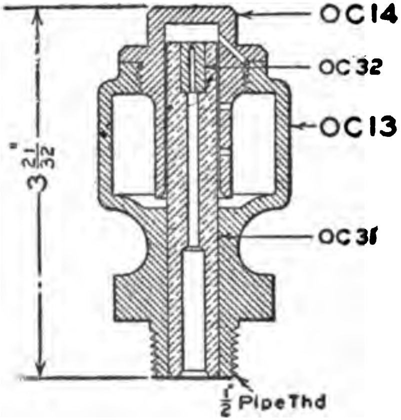


Fig. No. 145B

With this cup the quantity of oil fed to the air cylinder is governed by the diameter of the hole drilled in the plug, OC 32.

This automatic oil cup supplies oil to the air cylinders only when the air pump is working; so that although it performs the service required of it effectively, it also performs it with a maximum economy in the use of oil. Its use will increase the life of the air cylinders, packing rings and piston rod packing, as well as prevent hot pumps and the annoyance caused by the accumulation of the gum in other parts

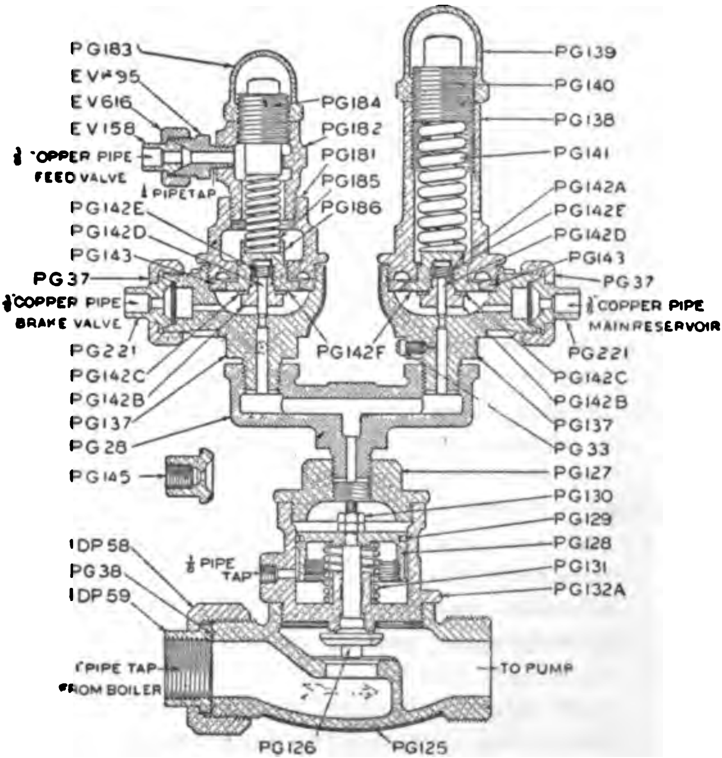


Fig. No. 146

of the engine equipment, due to the imperfect, wasteful and uneven lubrication of the air cylinders heretofore in vogue.

This cup should be filled before starting on a trip. Use only good cylinder oil to fill it, as other oils do not lubricate air cylinders on account of their low flash point. Never oil through the air inlets, as it clogs the passages and valves. The automatic cup can be filled whether the pump is running or not, and it is a good plan to start the pump first, so as to be sure that the small port in the plug, OC 32, is open. Be careful not to enlarge it when cleaning it out.

THE DUPLEX PUMP GOVERNOR

(Excess Pressure Type)

Fig. 146 illustrates this governor with the steam valve open. When handle of automatic brake valve is in either release, running or holding position, air from the main reservoir passes through the brake valve to the connection marked brake valve and into the chamber below the diaphragm. The feed valve pipe is connected at 158 and air pressure in the chamber above the diaphragm will therefore increase the pressure exerted by the regulating spring. The spring is adjusted for a pressure of about 30 pounds and the diaphragm will therefore be kept down until the main reservoir pressure under it becomes a little higher than the spring and air pressure together on top. The diaphragm will then rise and by unseating the pin valve allow air to pass to the top of the governor piston and move it downward to lessen the flow of steam past the steam valve until there is only enough to run the pump sufficiently to offset any loss of air in the brake system caused by leakage. Reduction of main reservoir pressure under the diaphragm allows the spring and air pressure on the other side to move the diaphragm down and thereby seat the pin valve. The air above the piston will escape through the small vent port, which is always open to the atmosphere, when the steam pressure and piston spring will raise the steam valve to the position shown in the illustration. This governor top is cut out in all positions of the automatic brake valve except release, running and holding.

The maximum pressure head of the governor must always have direct communication with the main reservoir, so that this head will control the pump when the other or excess pressure head is cut out by the brake valve, or the main reservoir cut-out cock is closed. Therefore connect the governor head marked main reservoir to the main reservoir cut-out cock, or so that it will be directly connected to the main reservoir at all times. When the main reservoir pressure overcomes the resistance of the regulating spring, and the diaphragm lifts the pin valve, air will flow to the top of the governor piston and control the pump as described above. While the handle of the automatic brake valve is in either lap, service or emergency positions, the maximum main reservoir pressure will be what the maximum pressure head of the governor has been adjusted for.

Each governor head has a small vent port to the atmosphere, through which air escapes whenever there is pressure above the governor piston, and one of these should be plugged, to prevent unnecessary waste of air.

Adjustment of the maximum pressure head is made by placing the handle of automatic brake valve into lap position, remoivng the cap nut of governor, and changing the tension of the spring, by means of the regulating nut, until the adjustment is such as to stop the pump when the desired maximum main reservoir pressure is obtained. This head should be adjusted for a pressure of 130 pounds.

Adjustment of the excess pressure head is made by placing the handle of automatic brake valve in running position, removing the cap nut and altering the tension of the spring, by means of the regulating nut, until the desired difference is obtained between main reservoir and brake pipe pressures. Adjust this head to give 30 pounds excess pressure in main reservoir.

PRINCIPLE OF THE BRAKE VALVE

Assume we have a cylinder shown in Fig. 141, containing an equalizing piston, and an exhaust valve as shown on the bottom of the piston, the pipe A receiving pressure from a reservoir of 70 pounds, a cut-out cock in pipe C and another in the upper pipe leading to chamber D, an equalizing reservoir E attached to the brake valve as shown. Let us assume we let air into chamber D and equalizing reservoir E until we obtain say 20 pounds, then open the cut-out cock in pipe C, letting the air into the brake pipe and against the triple piston as shown in Fig. 140, charging up until we have 70 pounds in the auxiliary reservoir and 70 pounds on the upper and lower sides of the equalizing piston as shown in Fig. 141. Here we

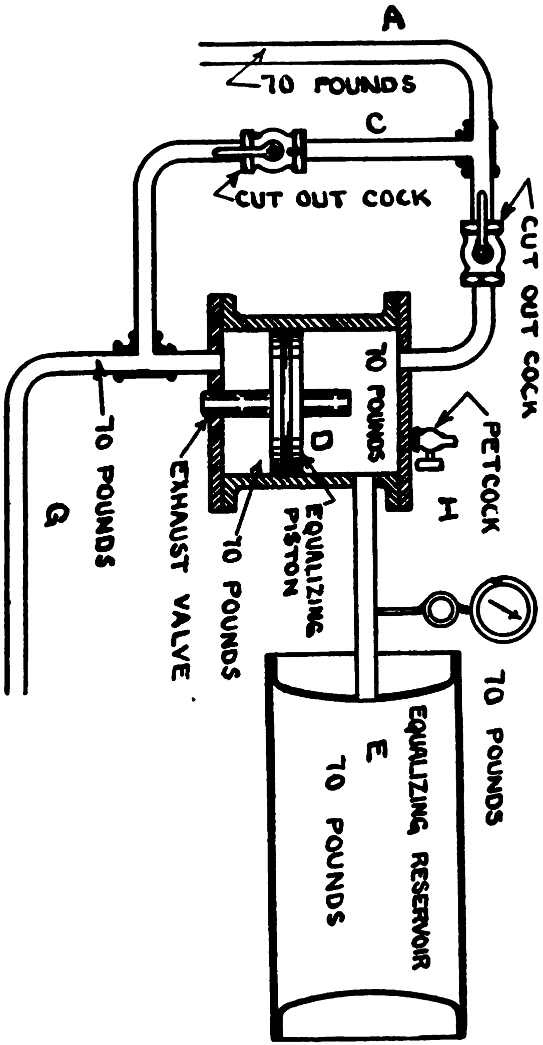

A
70 POUNDS
C
CUT OUT COCK
CUT OUT COCK
70 POUNDS
D
PETCOCK
H
70 POUNDS
G
EXHAUST VALVE
70 POUNDS
EQUALIZING PISTON
70 POUNDS
EQUALIZING RESERVOIR
E
70 POUNDS

Fig. No. 141

have equal pressures all around. Next referring to Fig. 142, let us assume we have closed the cut-out cock in pipe C and the one leading to chamber D as shown in the figure, and the pet cock H opened to make a 20 pound reduction in chamber D. What will happen? The pressure in chamber D and equalizing reservoir will be reduced below that in the brake pipe G, the pressure in G being greater will push the piston up, opening the brake pipe exhaust valve, and the pressure will flow out to the atmosphere, as shown by the arrow, until such time as the pressure below the piston has reduced down to that in chamber D or slightly below it. This will close the brake pipe exhaust valve holding the pressure remaining in the brake pipe, the triple valve being connected to the brake pipe will act as explained in Fig. 139.

Then why is it necessary to use the equalizing reservoir?

Because chamber D is very small and the amount of reduction could not be regulated as close as with the use of the reservoir. (You have a larger volume of air to draw from.)

It will also be seen that there will be a longer opening of the exhaust valve on a long train; that is, pet cock H discharges air from chamber D only.

While the exhaust valve may have to discharge the air from the brake pipe of 10 to 100 cars, more or less depending on the train length, and hence will have to remain open longer to accomplish this.

The release can be made by opening both cut-out cocks. This will recharge the brake pipe, as already explained.

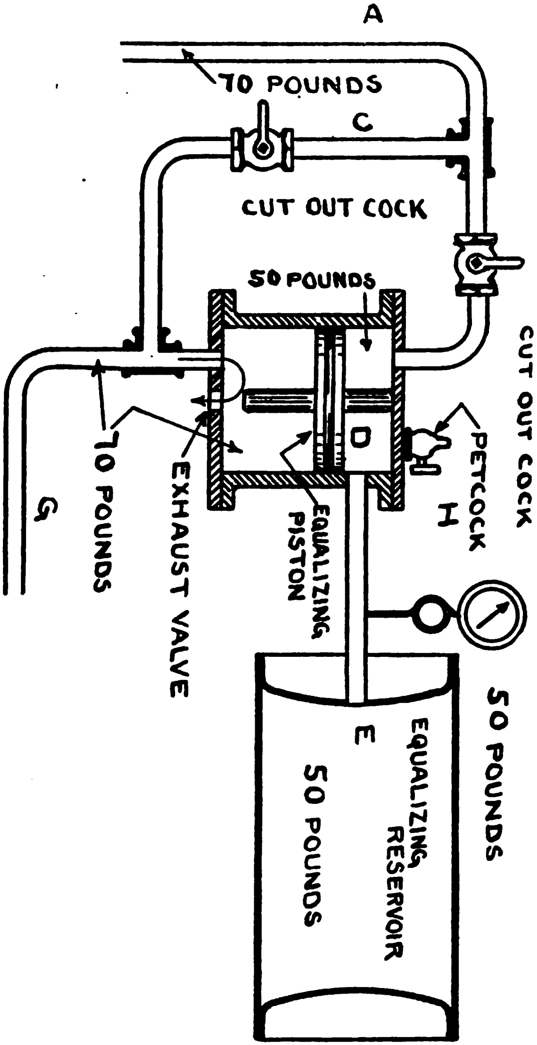

A
70 POUNDS
C
CUT OUT COCK
50 POUNDS
CUT OUT COCK
D
PETCOCK
H
70 POUNDS
EXHAUST VALVE
EQUALIZING PISTON
G
50 POUNDS
E
EQUALIZING RESERVOIR
50 POUNDS

Fig. No. 142

STYLE "L" STANDARD AUTOMATIC BRAKE VALVE

Fig. 147 illustrates the Standard Brake Valve, showing a horizontal and vertical section, also a plan of the rotary valve.

The valve is shown in the running position and all parts are represented as in actual service. Reading from left to right, the six positions are Release, Running, Holding, Lap, Service, and Emergency.

RELEASE POSITION

In the Release Position, main reservoir air passes from the top of the rotary valve, down through port in the rotary valve to port g in the seat, which leads to chamber D above Equalizing Piston, EV-677, thus moving Equalizing Piston, EV-677, down, until its stem seats on Bushing, EV-720, closing the port which leads from the train or brake pipe to the atmosphere by way of the Service Exhaust Fitting, EV-687. The air then passes from Chamber D to the Equalizing Reservoir at the connection marked 621. Air from the main reservoir also passes through port s in the rotary valve to port p in the seat, and then to the excess pressure top of pump governor by way of the connection marked Governor.

Air from the Feed Valve, at reduced pressure or the pressure which the train or brake pipe is to carry, enters the Brake Valve at the connection marked

Feed Valve, passes through port d in the seat to cavity f in the rotary valve, then through warning port i in the seat, which leads to the exhaust port EX and

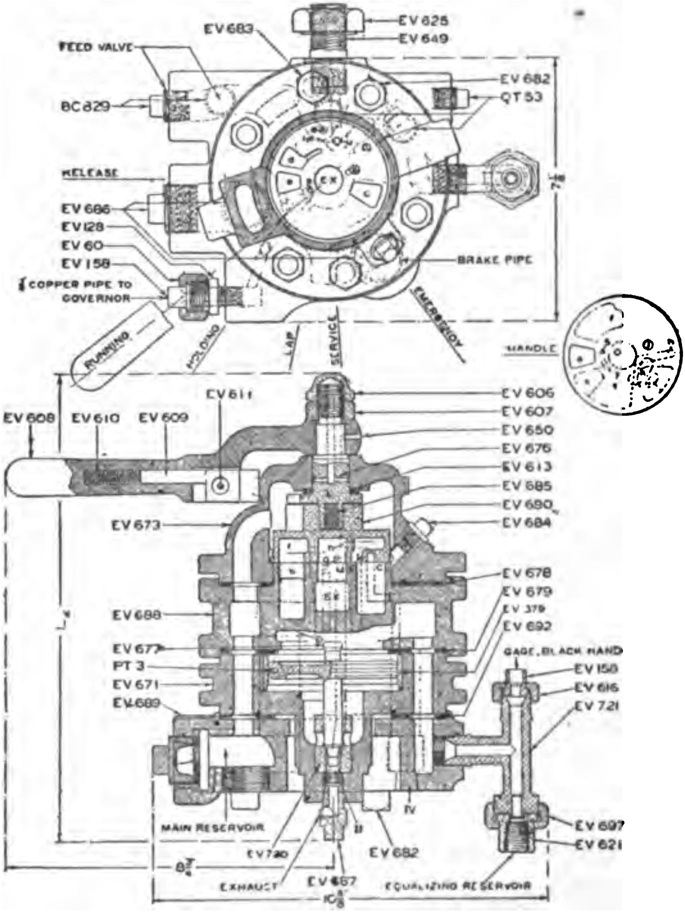


Fig. No. 147

the atmosphere, to warn the engineer that to prevent overcharging the auxiliary reservoirs, the handle of the brake valve should be moved from Release to Running Position, as soon as all brakes are released and auxiliary reservoirs nearly recharged; the time varying according to length of train.

RUNNING POSITION

In the Running Position main reservoir air is supplied to the train pipe at a pressure corresponding to the adjustment of the feed valve, which is connected to the main reservoir pipe.

In the Running Position, the locomotive or automatic control brakes are released by reason of the air contained in the control reservoir of the automatic control or distributing valve, flowing into the brake valve at the connection marked 3, passing through port l in the seat, ports h and o in the rotary valve and flowing through exhaust port EX in the seat to the atmosphere.

HOLDING POSITION

Holding position is for the purpose of holding the locomotive brakes on and not overcharging the train line, after the train brakes have been released.

This is accomplished by moving the handle of the brake valve to Holding Position, in which the rotary valve closes port l in the seat; thus retaining or holding the air in the control chamber of the automatic control or distributing valve. When desired, the locomotive brakes can be graduated off by short movements of the brake valve handle from Holding to Running Position, or released entirely by leaving it in Running Position.

LAP POSITION

In the Lap Position, all ports are closed. It is the position used in connection with service applications for graduating the service reductions and holding the brakes when applied. It is also used to prevent the loss of main reservoir air, when brakes are applied from the conductor's valve, bursted or parted hose, or from any cause outside of the brake valve itself.

SERVICE POSITION

This position causes gradual reduction of brake pipe pressure to produce service application. Air is discharged from chamber D and the equalizing reservoir, through preliminary exhaust port e in the seat, ports h and o in the rotary valve, and EX in the seat to the atmosphere. The other ports are all closed in Service Position, and gradual discharge of the air is insured by the size of port e. As the pressure in chamber D and the equalizing reservoir, which is above the equalizing piston, EV-677, has been reduced, the train pipe pressure or pressure below equalizing piston EV-677, is greater and causes the piston to rise, unseating its stem or valve, and discharging train pipe pressure through service exhaust fitting, EV-687, to the atmosphere at the point marked "Exhaust."

The operation just described may be repeated a number of times, during a service application, if desired or necessary, by returning the handle to Lap Position after each preliminary reduction. The first reduction, however, should be sufficient to insure all brakes going on and the following reductions according to necessity, all of which will vary, according to condition of brakes, train, gradient, atmospheric and other conditions met with in train operation.

When desired, or necessary, a continuous or complete service application can be made by placing the valve in Service Position, and leaving it there until a full service reduction has been made, when the valve should be placed in Lap Position to prevent waste of air. When the valve has been placed in Lap Position, after all service reductions, the train pipe pressure continues to flow to the atmosphere as described above, until the pressure of chamber D and the equalizing reservoir, above equalizing piston EV-677, is slightly greater than train pipe pressure below the equalizing piston, when the piston will gradually move down to its seat, closing the service or train line exhaust. After a service application, the brakes are released, as described in the Release and Running Positions.

EMERGENCY POSITION

In Emergency Position, the brakes are applied suddenly and with full force throughout the train. Train pipe pressure flows rapidly through ports x and o in the rotary valve, and port EX in the seat, to the atmosphere.

The pressure in chamber D and the equalizing reservoir is discharged through port g in the seat, ports t and o in the rotary valve, and port EX in the seat to the atmosphere. This causes equalizing piston, EV-677, to rise and a portion of the train pipe pressure to be discharged through service exhaust fitting, EV-687.

In the Emergency Position, main reservoir air flows from the connection marked Main Reservoir and the top of the rotary valve, down through port j in the rotary valve, port d and groove in the seat, cavity k in the rotary valve, groove and port n in the rotary valve and port u in the seat to the connection marked CR and the control reservoir of the automatic control or distributing valve, thus insuring the automatic maintenance of cylinder pressure.

After an Emergency application, the train brakes are released in Release Position, and the locomotive brakes are released in Running Position, the same as described for releasing a service application.

THE PRINCIPLE OF THE DISTRIBUTING VALVE

Referring to Fig. 160 we have the main reservoir A with a pressure of 90 pounds at pipe B, on the left, and reducing valve C set at 45 pounds pressure, allowing no pressure above 45 pounds to pass beyond it.

The pipe B branches off at the tee connection below, the cock to the left will be closed and not referred to again.

The distributing valve is shown in two pieces, the upper, the application portion; the lower, the equalizing portion.

Referring to the application portion E we have the

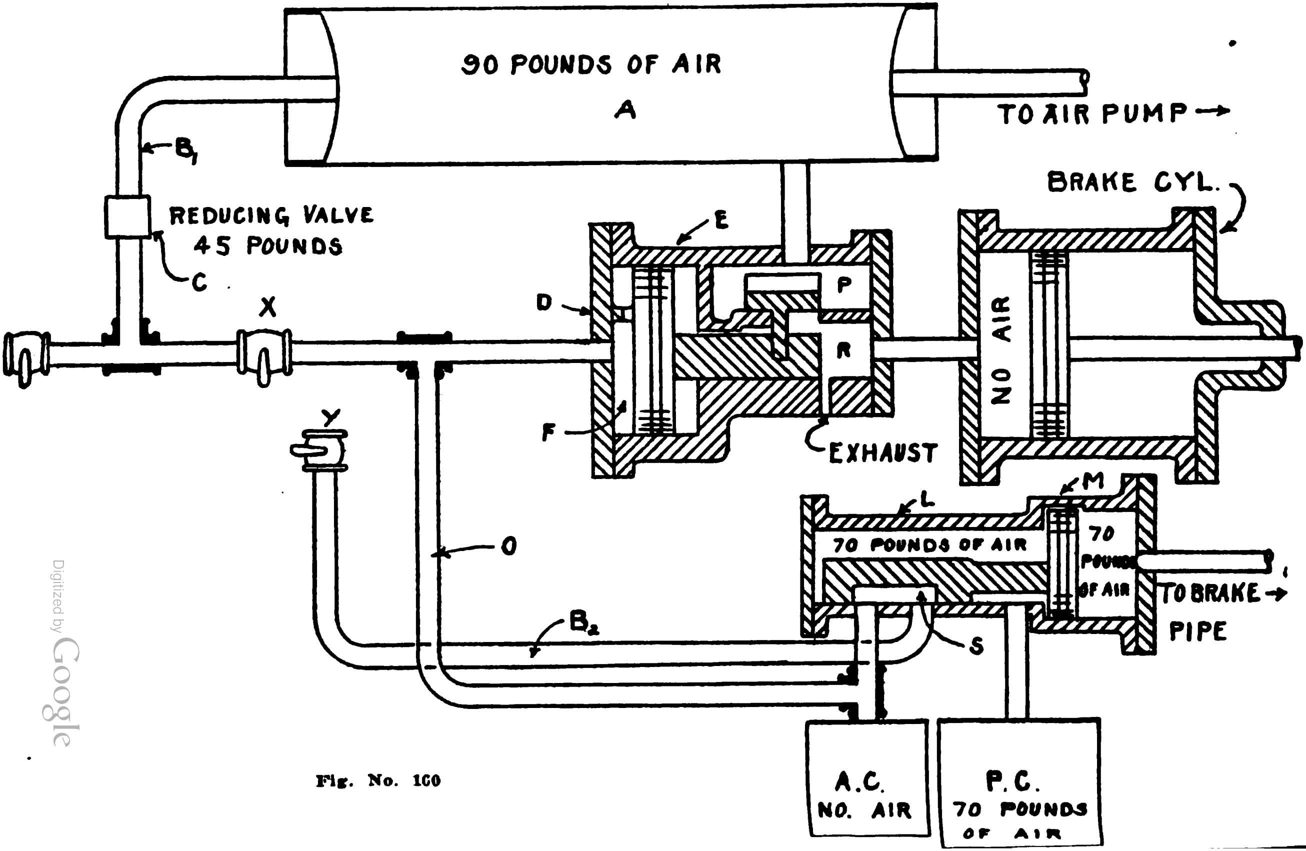

90 POUNDS OF AIR
A
TO AIR PUMP →
B1
REDUCING VALVE
45 POUNDS
C
X
E
D
F
P
R
EXHAUST
BRAKE CYL.
NO AIR
Y
O
B2
L
M
70 POUNDS OF AIR
70 POUNDS OF AIR
S
TO BRAKE → PIPE
A.C.
NO. AIR
P.C.
70 POUNDS
OF AIR

Fig. No. 160

application piston moving in chamber F with a flat valve (exhaust valve) moving in chamber R. It will be noticed there is a stem and slide valve on top of the exhaust valve; this is known as the application slide valve.

By referring to the figure, a pipe will be seen passing direct from the main reservoir A directly into chamber P, but none of this pressure can pass by the application slide valve in this position because it covers the port leading into chamber R.

A pipe to the brake cylinder is clearly shown and the exhaust port open showing that there is no pressure in the cylinder.

Next referring to the equalizing portion L. We have here the old triple valve again, the brake pipe pressure of 70 pounds entering behind the piston and flowing through the groove M into the inside portion of the piston and down around the spindle to the pressure chamber until they become equalized as described in the triple valve.

It will be noticed that pipes O and B_2 are connected together through the exhaust cavity S of the slide valve. This is the actual situation with the E. T. equipment. For example—when the equalizing piston is in full release both pipes O and B_2 are connected. There is a dotted line on B_2 where the pipes cross near the application chamber and at left that indicates B_2 passes behind where it is shown.

The brake pipe pressure of 70 pounds is shown here because it passes through the feed valve in the brake pipe on its way to the distributing valve and is reduced from main reservoir to brake pipe pressure.

OPERATION

Assuming we open cut-out cock X and cut-out cock Y is closed, what will happen? The pressure from the main reservoir will flow through the pipe B_1, through the reducing valve C, be reduced to 45 pounds and enter the chamber F against the piston and move it over, closing the exhaust port in R and moving the application slide valve in P over and a direct flow of air will result from the main reservoir A into the brake cylinder.

When the air passes by cut-out cock X it passes into chamber F and down through O into application chamber A C, and of course up under the cavity S of the slide valve over into pipe B_2 and up against the cut-out cock Y. Then if the cut-out cock X is closed and Y opened the air will flow out of application chamber and chamber F, causing the pressure on the right of the application piston to move it back against the head D and release the brake explained in detail further on.

The names of pipes:

Pipe O would be known as the application cylinder pipe.

Pipe B_2 the distributing valve release pipe.

The pipe to chamber P, the main reservoir supply pipe.

The pipe between chamber R and the brake cylinder, the brake cylinder branch pipe.

The pipe on the extreme right of the equalizing portion L would be the brake pipe branch.

Fig. 161 shows the distributing valve with the essential parts.

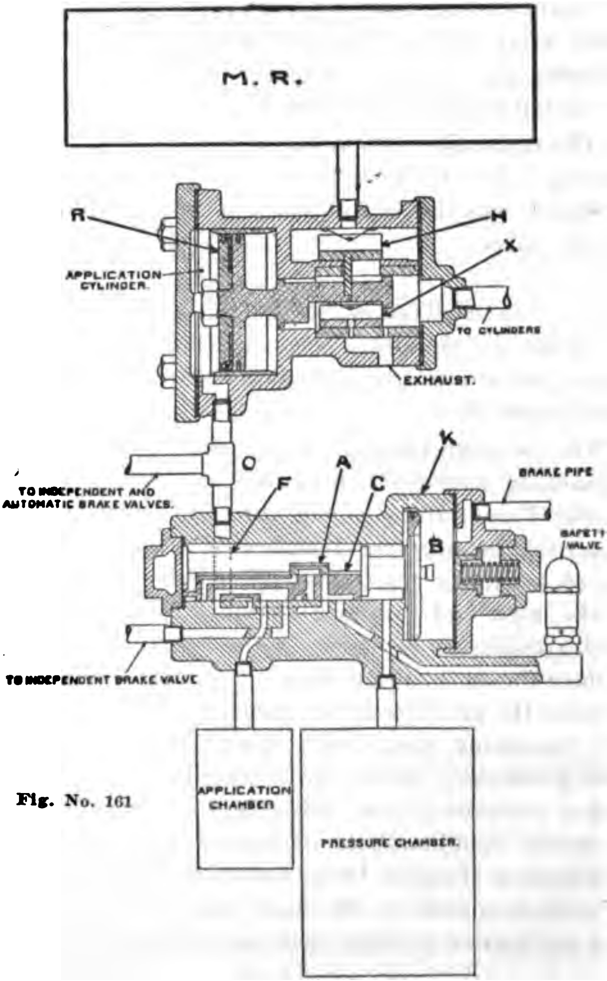


Fig. No. 161

Here we have the main reservoir and pipe connecting the chamber in which the application slide valve

H ~~operates the application piston~~ R, the application slide valve H, the exhaust valve X, the application cylinder pipe O connected to the application chamber as shown by the dotted line F.

The ~~equalizing piston B, the feed~~ port K, the graduating valve A, the slide valve C, connecting the application chamber through the ports as shown to the safety valve.

AUTOMATIC OPERATION

As already described, main reservoir pressure is always present in the chamber above the application slide valve H.

The pressure from the brake pipe enters behind the equalizing piston B, through the connection marked Brake Pipe, passes slowly through the feed port K, entering the pressure chamber, charging it the same as an auxiliary reservoir. After the pressure in the brake pipe and pressure chamber become equalized and a reduction be made in the brake pipe, this will reduce the pressure on the plain side of the equalizing piston; the pressure in the pressure chamber will force the equalizing piston over, carrying with it the slide and graduating valves, uncovering the ports and making a communication between the application and pressure chambers, the amount of air passing to the application chamber being determined by the amount of reduction made in the brake pipe. The air entering the application chamber will pass up through the port F and pipe O to the application cylinder and against piston R, moving it to the right, moving slide valve H to the right, closing the exhaust valve X and opening a communication from the main reservoir to the brake cylinder until such time as the pressure in the brake cylinder becomes equal to that in the application cylinder, when it will move back to lap, cutting off the flow of air from the main reservoir to the brake cylinder.

The pressure in the brake cylinder passes back to the inside or right side of the application piston R, so there is always a balance here. This causes a reduction in pressure when brake cylinder leakage is present and valve H is lapped. The pressure in the application cylinder will force it over to the right to open and replenish the leakage from the main reservoir.

The independent operation in principle is similar to that already described in the first principle of the distributing valve.

The safety valve is in communication with the application cylinder or chamber in all positions except automatic service lap.

The safety valve is set to carry 86 pounds pressure in the application cylinder and chamber.

PROPER METHOD OF HANDLING BROKEN PIPES

Pipe No. 1—**Main Reservoir Supply Pipe.** If repairs cannot be made, close cut-out cock or plug the pipe; proceed with train brakes only.

Pipe No. 2—**Application Cylinder Pipe.** Plug connection at distributing valve; brakes can then be operated on both engine and train with the automatic valve only.

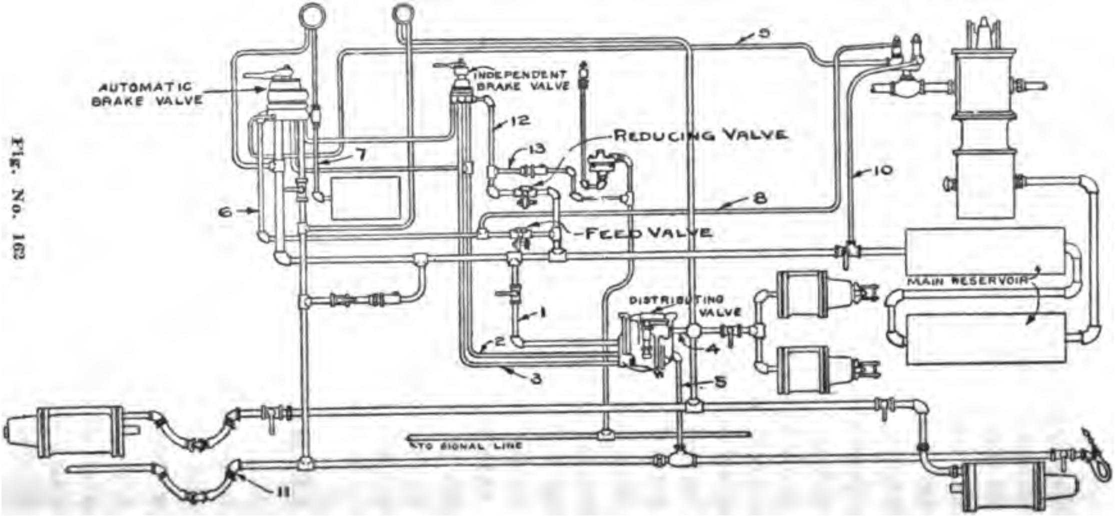

AUTOMATIC BRAKE VALVE
INDEPENDENT BRAKE VALVE
REDUCING VALVE
FEED VALVE
DISTRIBUTING VALVE
MAIN RESERVOIR
TO SIGNAL LINE

Fig. No. 162

Pipe No. 3—**Distributing Valve Release Pipe.** Proceed without making any repairs and use the automatic brake valve at all times.

Pipe No. 4—**Brake Cylinder Pipe.** If this pipe should break at the distributing valve, close the cut-out cock in the main reservoir supply pipe; proceed with train brakes only. If failure occurs at any other point, close cut-out cock immediately back of the break.

Pipe No. 5—**Brake Pipe Branch to Distributing Valve.** Plug the end leading from the brake pipe and release locomotive brakes with the independent brake valve. Train brakes must then be operated with the automatic brake valve and the engine brakes with the independent brake valve, using the independent brake valve for handling the locomotive brakes at all times.

Pipe No. 6—**Feed Valve Pipe.** If breakage occurs at any point between the feed valve and brake valve, remove the tension on the regulating spring in feed valve by turning the hand wheel to the left and plug the pipe connection towards the automatic brake valve. If the locomotive is equipped with the excess pressure governor it will also be necessary to plug Pipe No. 9. Charge engine and train brakes with automatic brake valve in full release. When applying brakes with the automatic brake valve, be sure and reduce the pressure enough in the brake pipe to make a difference between the main reservoir and brake pipe pressures so that a proper release can be obtained. Go to release position to release train brakes, then to running position to release locomotive brakes, and then place the brake valve in release position to charge all equipment.

Pipe No. 7—**Equalizing Reservoir Pipe.** If this pipe breaks between the brake valve and reservoir, plug connection at brake valve and plug the brake pipe exhaust. The brakes can then be operated by a careful use of the emergency position. If the pipe breaks between the brake valve and the large duplex gauge, plug the connection at the Tee fitting towards the gauge. Brakes can then be operated in the usual manner. The large gauge in this case will show no equalizing reservoir pressure.

Pipe No. 8—**Top Pipe Connection to Excess Pressure Governor.** Plug connection at feed valve pipe and plug Pipe No. 9.

Pipe No. 9—**Diaphragm Chamber to Excess pressure Governor Pipe.** Plug connection at the brake valve and proceed.

Pipe No. 10—**Maximum Governor Pipe.** Plug pipe at main reservoir connection. Under these conditions the excess pressure governor will control the pump while the brake valve handle is in full release, running and holding position. Be careful not to leave the brake valve handle on lap service or emergency position too long, as there is nothing to stop the pump while brake valve is in these positions.

Pipe No. 11—**Brake Pipe.** If this pipe should break at any point between engine and rear of tender, put a gasket in the union at or near cab bracket, couple the brake pipe hose to signal hose on pilot, couple the signal hose on rear of tender to the brake pipe hose on the car. Brakes can then be operated on the engine, tender, and train. After proper test of brakes, proceed without the use of the signal equipment.

Pipe No. 12—**Reducing Valve Pipe to Independent Brake Valve.** Remove tension on regulating spring in reducing valve by turning adjusting nut to the left. Plug the pipe, after which readjust the reducing valve so that the signal can be operated. Proceed without use of independent brake valve.

Pipe No. 13—**Signal Pipe.** Remove the tension on the regulating spring in reducing valve by turning adjusting nut to the left. Plug the pipe leading to the signal equipment, after which readjust the reducing valve so that the independent brake valve can be operated.

DISTRIBUTING VALVE ROAD DEFECTS

Engine brake does not apply with automatic reduction while coupled to train but works all right when the engine is light. This is caused by a leakage past the equalizing piston packing ring. When the engine is coupled to a train, it takes longer for the pressure to reduce in the brake pipe during a service application. This gives an opportunity for the air in the pressure chamber to feed back into the brake pipe without moving the equalizing piston, whereas with the light engine the pressure is reduced much quicker because of the smaller volume of air to be handled through the service exhaust fitting in the brake valve, not giving time for the pressure to equalize as it would with the long train.

MAIN RESERVOIR PRESSURE DROPS EXCESSIVELY DURING AN AUTOMATIC OR INDEPENDENT BRAKE APPLICATION

This is due to a broken brake cylinder pipe, a brake cylinder packing, a head gasket or a broken brake cylinder push rod letting the piston turn over in the cylinder.

Often when coupling to an uncharged train the engineer may believe the angle cock on the rear end is open or some defect in the train brake pipe because there will be a large drop in both main reservoir and brake pipe pressure on the engine when the pressure is turned into the train brake pipe. The broken brake cylinder pipe will reduce the main reservoir pressure so suddenly that often the brake pipe pressure will lift the automatic rotary valve, causing the pressure to flow into the main reservoir and out via the broken pipe.

The action of the distributing valve is as follows: When the engine angle cock is opened to admit air to the train brake pipe it makes a reduction on the plain side of the equalizing piston. This moves over, allowing the pressure chamber air to flow into the application chamber and cylinder. This pushes the application piston over, letting air by the application slide valve into the brake cylinder pipe and out through the broken pipe or piston to the atmosphere.

To determine whether the trouble is on the engine or train when charging, place the independent brake valve in release position; this will let the air out of the application chamber and the spring on the end of the application piston will cause the slide valve to move to lap, shutting off the flow of main reservoir pressure. Should the trouble be here the pump will bring the pressure up as it should.

BRAKES SET TOO HARD IN SERVICE APPLICATION

This is generally due to a dry application slide valve making it necessary to build up too much pressure in the application cylinder and chamber before the piston will start over to admit air into the brake cylinder, and will cause a high building up of pressure on the brake cylinder side of the application piston before it will move to lap position.

The remedy to apply on the road is as follows: Close the main reservoir, cut-out cock, take out the small plug in the application slide valve cap, turn in a small amount of valve oil, then move the independent brake valve to application and release a few times to work the oil in and over the valve and seat. Reinsert the plug cut in the main reservoir cock and try the brake to see that it is working properly.

When reaching the terminal the valve should be reported and cleaned.

BRAKE WILL NOT APPLY ON THE SECOND ENGINE WHEN DOUBLEHEADING AND DOUBLEHEADING COCK IS CLOSED

This is caused by the application cylinder and release pipes being crossed over. Remedy while on road, carefully watch independent brake valve gauge so there will be no wheel sliding carrying the independent brake valve on lap whenever an application is being made on the leading engine. This will be manifested by a blow through the application cylinder pipe into the automatic brake valve exhaust during the application. For example—the independent brake valve should be lapped just as soon as the blow is heard and when the brake pipe hand on the small duplex gauge rises move the independent brake valve handle to running position. When time is had the pipes should be changed to their proper location.

HANDLING DEAD ENGINES

Many engines will be found without the dead engine fixtures and in such a case, whenever it is necessary to bring in an engine in a freight train without steam or water in the boiler, the following method should be used:

Turn back the adjusting handle on the freed valve, place both brake valves in running position, remove the service exhaust, fitting from the automatic brake valve, roll a piece of paper in the shape of a cone or stopper for a bottle, press it tightly into the inside of the exhaust, fitting so that the pressure will force it tightly into place; insert the fitting into the brake valve, then connect up the air hose and apply air to the brake system.

This scheme makes a check valve of the feed valve, by reversing the flow of air passing through the feed valve, using the slide valve as the check. For example—the air passing up through the brake pipe will pass into the feed valve pipe under the slide valve, lifting it against the spring, thus allowing the air to pass through the brake valve and over into the main reservoir.

Just as soon as the main reservoir pressure and that in the brake pipe become nearly the same, the slide valve spring will seat the valve and no more pressure can flow back to the brake pipe.

When a reduction is made in brake pipe pressure the distributing valve will operate the same on the dead engine as though the application was made with its automatic brake valve. The slide valve of the feed valve will prevent any pressure passing back to the brake pipe, thus making this operation positive.

When the release is made the distributing valve acts the same as the automatic release described in the foregoing pages. It will be necessary to screw back on the distributing valve, safety valve, so the pressure will not exceed 35 pounds. This can be accomplished by having a man in the cab, and main reservoir pressure of about 70 pounds, apply the independent brake valve, watch the brake cylinder gauge, adjust the safety valve accordingly, making sure that both valves are left in running position after completing the work.

NEW YORK L. T. EQUIPMENT

Operation

For operating the Automatic Control Equipment the instructions are about the same as for the combined automatic and straight air brake, viz.:

When not in use, keep handle of automatic brake valve in running position, and handle of straight air brake valve in release position.

For service application, move handle of the automatic brake valve to the service position until the required reduction is made, then back to lap position, which is the position used to keep brakes applied.

To release the train brakes, move handle of the automatic brake valve to the release position and hold it there until all triple valves are released; if the locomotive brakes are to be released at once, use running position, but if they are to be held on for a time, move to holding position, and then graduate off as desired, by short movements between running and holding positions.

How long to hold the automatic brake valve in release and holding positions depends upon the length of train and other conditions, such as speed, grade, etc.

For emergency application, move the handle of automatic brake valve to emergency position and leave it there until the train is brought to a stop.

The desirable two application stop for passenger service is very easily made with the Automatic Control Equipment. Use the automatic brake valve and make the first application strong enough to reduce speed to about fifteen (15) miles an hour; then move handle into release position and immediately return to running position for two or three seconds before making the second application of the brakes.

With passenger trains of less than ten cars, and where the grade conditions will permit, the final release should be made by moving the handle to release position and returning it immediately to running position with the object of getting the train and locomotive released by the time the train is stopped; with ten or more cars, hold the brakes on until the train comes to a stop.

When the straight air brake is used alone, carry automatic brake valve handle in running position, and release the straight air brake, when desired, by moving handle of straight air brake valve into the release position.

With long trains, careful operation of the straight air locomotive brake is necessary to avoid injury to cars and contents, by bunching the train too suddenly, or letting the slack run out with a jerk.

If emergency conditions occur while the straight air locomotive brake is already on, immediately set the automatic brake also, and the safety valve will keep the brake cylinder pressure within safe limits.

On heavy grades, use the locomotive and train brakes alternately, so that the tires of the driving wheels will not become overheated and that the pressure retaining valves may have assistance in controlling the train while the auxiliary reservoirs are being recharged. To use the locomotive and train brakes alternately in this manner, proceed as follows: When train brakes are set, release the locomotive brakes by placing the handle of the straight air brake valve in locomotive automatic release position; then apply locomotive brakes and release the train brakes. After again applying brakes on the train, release the locomotive brakes, as described above.

If all brakes have been automatically applied in the usual manner, and it is desired to release only the locomotive brakes; either wholly or gradually, this can be done by placing the handle of the straight air brake valve in locomotive automatic release position.

In operating the Automatic Control Equipment, observe the pressure obtained in the locomotive brake cylinders, as shown by the red hand of the gauge connected to them.

The independent or straight air brake is a very effective and desirable safety provision, and is capable of holding, on ordinary grades, a train of the usual tonnage handled on such grades, after the train has been brought to a stop and the slack is all in. It is always advisable, however, to have the automatic brake in condition to apply also, should anything occur to make this necessary, and to set hand brakes whenever it seems advisable.

When the engine is standing at a water crane or coal chute, or when the engineer is working about it, the straight air brake valve should be left in the applied position.

If the brakes are automatically applied by parting of train or burst hose, or if the brakes have been set with the conductor's valve, the automatic brake valve handle must be placed in lap position.

If more than one locomotive is attached to a train, all except the one from which the brakes are being

Automatic Control Valve.

Full Release.

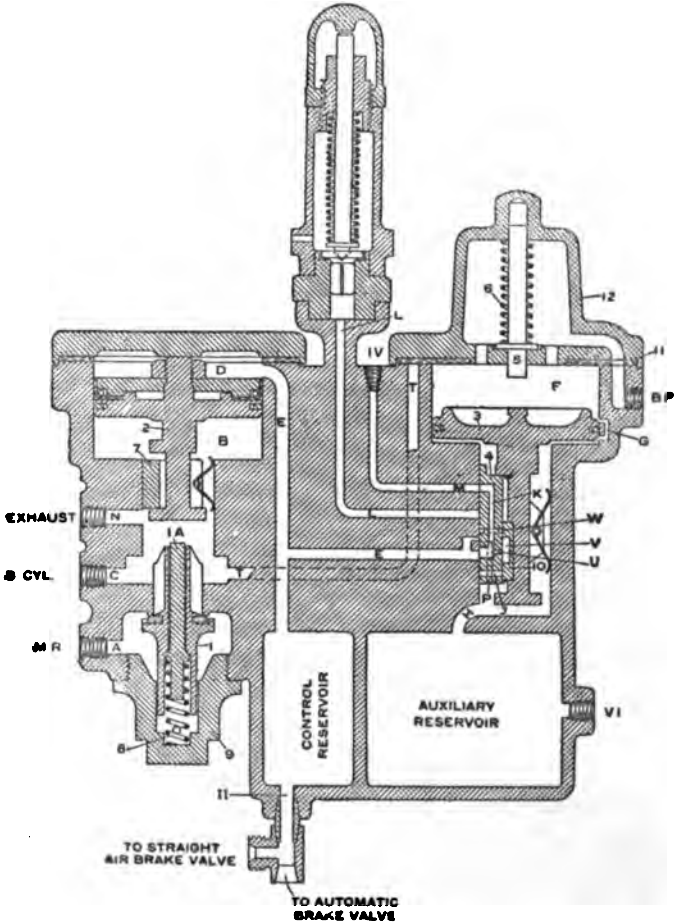


Fig. No. 163

operated must have the cut-out cock closed in the brake pipe under the automatic brake valve, and the handles of the automatic brake valves carried in running position.

Always try both brake valves before leaving the round house, and make sure that there are no leaks of importance. The pipes must be perfectly tight that connect the automatic control valve to the automatic brake valve.

FULL RELEASE OR NORMAL POSITION

Figure 163 shows the parts in their normal position, of full release. In the chamber about control valve 1 and 1A there is always main reservoir pressure, which has free communication through A. On the under side of control piston 2, the chamber B is always connected to the brake cylinders through passage C and the brake cylinder pipe.

Control cylinder D, above piston 2, is connected by passage E to the slide valve seat, and through passage K in slide valve 4, which registers with port M, to the automatic brake valve through the control cylinder release pipe at IV.

CHARGING POSITION

As shown by Figure 163, the chamber F is connected to the brake pipe at the place marked BP. When the parts are in release position, as shown, air from the brake pipe passes around piston 3, through charging port G at the top of piston, into the chamber around slide valve 4, and thence through port H to the auxiliary reservoir, until the air pressure is equalized on both sides of piston 3.

The principle of operation is similar to that of the E. T. equipment already described.

THE TYPE K FREIGHT TRIPLE VALVE

The New York Air Brake Company's Type "K" Quick-Action, Quick-Service, Uniform-Release, Uniform-Recharge Freight Triple Valve, illustrated and described, has met with so widespread and favorable a reception, since its introduction into general railroad service, and has been adopted as standard by so many roads that it is now considered the standard and recommended triple valve for freight service instead of the old and well-known (Types F and H) triple valves.

The K triple valve embodies every feature of the old type, and in addition three new ones called the Quick Service, Uniform Release, and Uniform Recharge. It not only works in perfect harmony with the old valves, but many tests under road service conditions have shown that it greatly improves the action of the latter when they are mixed in the same train.

QUICK SERVICE

The quick-service feature was added to bring about a more certain, more uniform and quicker application of the brakes in service applications on long trains. To make this necessity more clear, it is necessary to have in mind the following: The rate of brake pipe reduction for service applications with the old brake system is determined by the exhaust port in the brake valve and by the frictional resistance of the pipe. As this is constant, it is plain that the longer the train the slower will be the rate at which pressure in the brake pipe will reduce, and as the air cannot flow to the brake cylinder any more rapidly than the brake pipe pressure is being reduced, it is plain that toward the rear of long trains only a very slow application of the brakes takes place, even when they apply at all. This slow rate of brake pipe reduction not only results in a slow application but many times in the failure of individual brakes to apply. This is brought about by the fact that when the pressure is reducing very slowly in the brake pipe it can feed back at the same rate from the auxiliary reservoir, through the triple valve feed groove into the brake pipe, and thus there is no difference of pressure created to move the

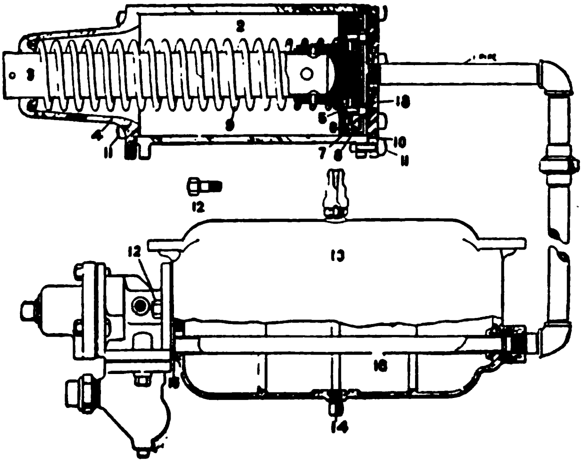


Fig. No. 164. Freight Brake Equipment

triple valve to application position. Another reason for failure to apply is that even though the triple valve moves to service position the air flows so slowly from the auxiliary reservoir to the brake cylinder that it passes through the leakage groove in the brake cylinder or past the packing leather to the atmosphere, and therefore the pressure does not build up in the cylinder sufficiently to force the piston out and the shoes against the wheels.

Furthermore, to bring about proper operation of the brakes in a long train not only should the brake pipe pressure be reduced as rapidly, but also as uniformly as possible. As it is impossible to increase the opening at the brake valve without increasing the likelihood of obtaining undesired quick action, and also as it would be certain to bring about a quicker and heavier brake application at the head end of the train than at the rear, with the consequent shocks and danger of breaking in two on the recoil, it was found necessary to provide other and local means for reducing the brake pipe pressure more rapidly and uniformly so that these things would be avoided. These means exist in the quick-service feature of the triple valve, which consists of an opening from the brake pipe to the brake cylinder when triple valve is in service position, which port is subject to graduation the same as the ordinary service port of the triple valve. From this it will be seen that when the reduction of the brake pipe pressure is commenced at the brake valve and the first triple valve reaches application position, a supplementary reduction of brake pipe pressure takes place at that triple valve, thus causing the more rapid application of the next triple valve; this in turn of the next one and so on throughout the train, thus producing what may be termed "serial service application of the brakes."

With the Type K triple valve, certain undesirable features of the former valves have been overcome and the following additional features derived:

(1) More uniform charging of the entire train, consequently more uniform cylinder pressure and application of the brakes.

(2) Ability to remain in release position longer without the resultant overcharging of the forward end of the train (avoiding the consequent reapplication of the brakes due to back flow of air).

(3) Greater volume and pressure of air flowing toward the rear end of the train.

(4) Saving of air which would otherwise go to the auxiliary reservoir, then to the cylinders by reapplication of the brakes and to the atmosphere through the triple valves, this saving being due to the small charging ports preventing the overcharging of auxiliaries.

(5) As a result, a much better control of the train by the engineer, shorter stops, great reduction in shocks and break-in-twos, greater freedom from relays and greatly reduced air consumption.

Under the same conditions as the old equipment, the Type K triple valve will give approximately one pound higher equalization pressure, due to the air entering the cylinder through the quick service ports. This feature automatically goes out of service, however, where the brake pipe pressure is being reduced at the proper rate, as on short trains, and, in all cases, after about 25 pounds brake cylinder pressure has been obtained.

In studying the operation of the Type K triple valve, either as a single valve or as a part of the train equipment, it must be constantly kept in mind that the greater efficiency of the Type K triple valve is not due to a higher brake cylinder pressure being obtained with this than with the old valve (this increase being only about one pound for equalization, as already explained) but because

1st—The brakes on a long train apply in less time than with the old valves.

2nd—All the brakes apply.

3rd—The air flowing to the brake cylinders through the quick-service ports helps to compensate for the displacement of the brake cylinder piston, thus making the brake much more effective for light reductions.

MANIPULATION

No special instructions are required by the engineers to handle trains partially or wholly fitted with the K triple valve. The automatic brake valve should be handled as good practice requires with the F and H triple valves.

In releasing an individual brake by means of the release valve on the auxiliary reservoir, the brake pipe being charged, the release valve should be held open only until the exhaust is heard to start. In this way, if the auxiliary reservoir pressure is reduced only slightly below that in the brake pipe, the triple valve piston will go only to release position, not to retarded

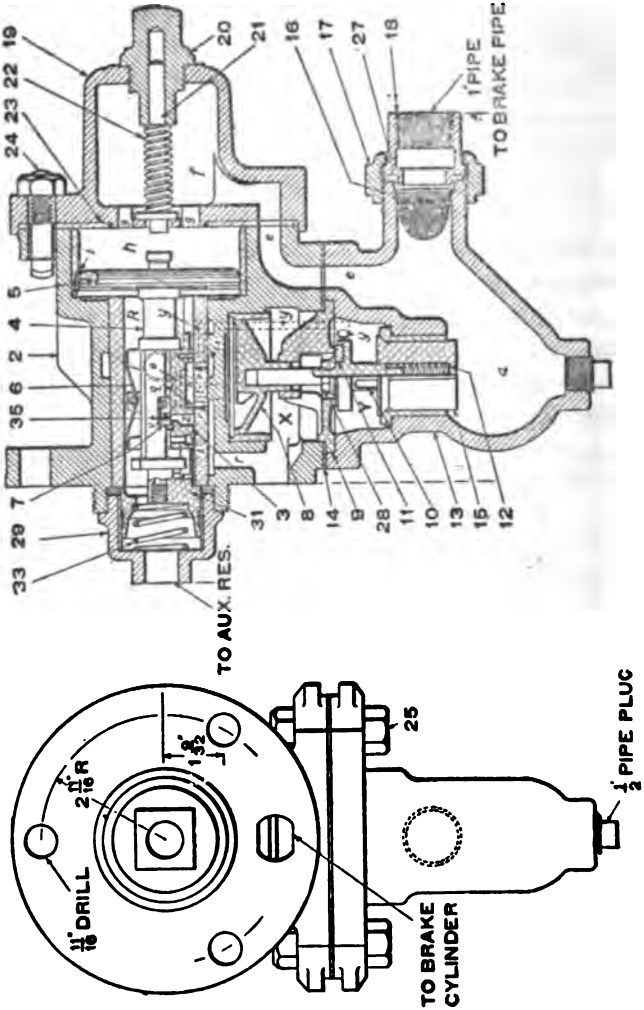

1" PIPE
TO BRAKE PIPE
TO AUX. RES.
1 3/32"
2 11/16" R
11/16" DRILL
1/2" PIPE PLUG
TO BRAKE CYLINDER

Fig. No. 165

release position, and the release will be as rapid as with the old type of valve. If the auxiliary reservoir pressure is reduced much below that in the brake pipe the piston will go to retarded release position and the release will be slower. Where there is no air in the brake pipe the brake must be released in the usual way, viz., by holding the release valve open until all the air has escaped.

Fig. 165 is vertical cross-sections of this valve, and the names of the various parts are as follows:

2, Valve Body; 3, Slide Valve; 4, Main Piston; 5, Piston Ring; 6, Slide Valve Spring; 7, Graduating Valve; 8, Emergency Piston; 9, Emergency Valve Seat; 10, Emergency Valve; 11, Emergency Valve Rubber Seat; 12, Check Valve Spring; 13, Check Valve Case; 14, Check Valve Case Gasket; 15, Check Valve; 16, Air Strainer; 17, Union Nut; 18, Union Swivel; 19, Cylinder Cap; 20, Graduating Stem Nut; 21, Graduating Stem; 22, Graduating Spring; 23, Cylinder Cap Gasket; 24, Bolt and Nut; 25, Cap Screw; 27, Union Gasket; 28, Emergency Valve Nut; 29, Retarding Device Body; 31, Retarding Stem; 33, Retarding Spring; 35, Graduating Valve Spring.

TRAIN HANDLING FREIGHT SERVICE

Effect of Piston Travel on Brake Cylinder Pressure

Referring to Figure 167, we have the tank A having 70 pounds of air pressure contained in it and the tank B containing no pressure, pipe C and valve D connecting both together. Now assuming the tank A is 2½ times larger than tank B and the valve D is opened the pressure in A will flow into B and both will become equalized at 50 pounds, as shown in example B.

Then assume in Fig. 168 we have 70 pounds of air and open the valve D just enough to let ten pounds of air from A into B, and just as soon as the pressure in A is down to 60, close valve D. The pressure in tank B will equal 25 pounds. Why? Because A is 2½ times the size of B and therefore 10 pounds of air taken from A and put into B will be 2½ times 10 or 25 pounds.

EFFECT OF PISTON TRAVEL ON BRAKE CYLINDER PRESSURE

EXAMPLE "A"

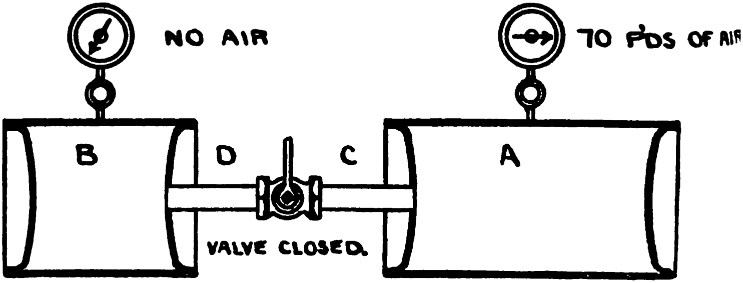


Fig. No. 167

Next assume the piston F in Fig. 169 to be at E in the tank B, what would result if the valve D was opened? The tank B would be larger, consequently would take much more air out of A and the pressure would equalize lower.

Then suppose the end of the tank B was at the piston F, what would result if the valve D were open?

it would take less air to fill B and therefore the pressure in A would equalize with B at a much higher pressure. The ten pounds used in the above example would not be 25 pounds pressure, but higher in B. Why? Because B is smaller than before. The pressure developed in the brake cylinder of the ordinary freight and passenger equipment excepting in the later, the Westinghouse P C equipments are identical with the description given. The proportions that exist between the application and pressure chambers of the distributing valve are 2½ to 1.

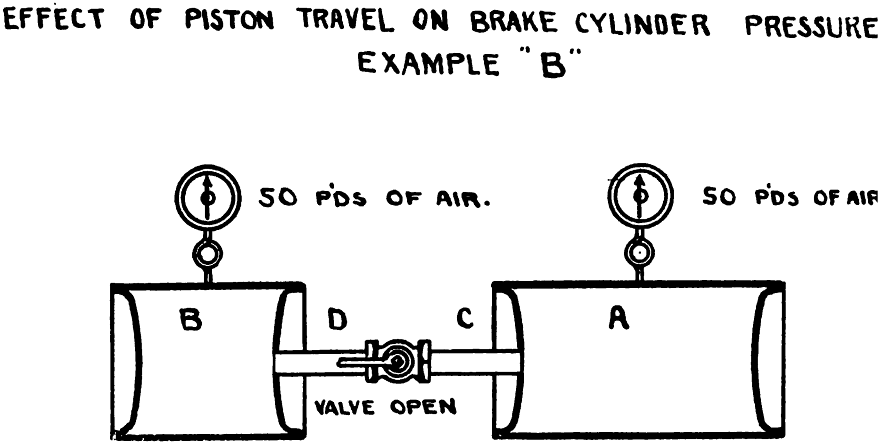

EFFECT OF PISTON TRAVEL ON BRAKE CYLINDER PRESSURE
EXAMPLE "B"

Fig. No. 168

The cylinder pressure obtained for any given brake pipe reduction is intended to be as nearly uniform as possible on all cars, and it should be. However, the cylinder pressures are not uniform; the unequal piston travel and brake cylinder leakage that is present on nearly every freight train makes impossible of attainment. In brake operation the piston travel is of such importance that it varies the effect of every operation of the brakes in so far as power is concerned. It varies the time required to obtain the braking power expected to be had from a given brake pipe reduction. It is possible to get several times the braking power on one car as compared to another, due wholly to the variation in piston travel. It is also a condition over which the engineer does not have control. These

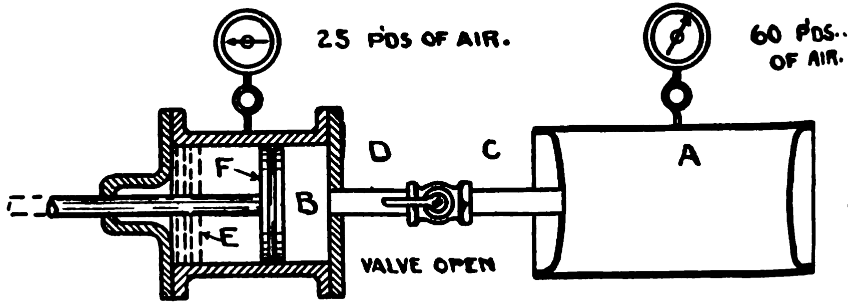

EFFECT OF PISTON TRAVEL ON BRAKE CYLINDER PRESSURE
EXAMPLE "C"

Fig. No. 169

varying brake cylinder pressures that cause excessive braking power on some cars and little or none on others, both of which produce shocks due to the surging of the train and slid flat wheels, caused by short piston travel on one car placed in a train near other cars having excessive travel.

TIME NECESSARY TO APPLY BRAKES

The time element is something that must be taken into consideration. This affects both the application and release of brakes. It may not cause trouble with short trains, but on long trains there is a considerable interval of time between the starting the application of brakes on the head end and rear end of the train, in fact, the brakes on the head end may have reached a high cylinder pressure for the reduction made before they commence to apply on the rear and unless good judgment is used in keeping the train stretched or bunched, bad results may occur when the brakes apply at the rear. The rise of cylinder pressure is different on long than on short trains, since the cylinder pressure cannot rise at any faster rate than the brake pipe pressure is being reduced, this varies with the length of train. The time element, therefore, must be considered with every brake application.

TRAINS CONSISTING OF LOADS AND EMPTIES

A difficult situation involved in freight train control is that caused by handling loads and empties.

These varying conditions produce excessive braking power on some cars and little or none on others, both of which produce shocks due to the surging of the train, and flat wheels, due to cars being pulled or shoved until wheel sliding or excessive heating takes place.

For example: Suppose that two cars are coupled together, each having a light weight of 35,000 pounds, with the standard 8 inch equipment, the first car having 11 inch piston travel and the second car 4 inch. If a full service application is necessary to stop the two cars, a brake pipe reduction of a sufficient amount must be made to equalize the brake cylinder and auxiliary reservoir pressure of both will be 23 pounds, although 11 pounds would be sufficient for the second car. Therefore, 12 pounds of brake pipe air is wasted from the second car. The second car would obtain a cylinder pressure of 59 pounds, while the head car only obtains a pressure of 47 pounds.

It is evident from this that a uniform piston travel is most desirable. If it is long, the brake cylinder pressure is thereby reduced and the efficiency low; a greater quantity of air is consumed in brake applications than would otherwise be necessary, entailing greater demand upon the air compressor. If the piston travel is too short, it is liable to cause the brake shoes to drag upon the wheels when brakes are released, and by too high a cylinder pressure, with the possibility of wheel sliding and rough stops when brakes are applied.

CHARGING AND TESTING

It is essential to have the maximum main reservoir pressure when coupling to the train. In charging, use full release position until the brake pipe pressure has almost reached the adjustment of the feed valve, then move brake valve handle to running position, at which time the brake pipe pressure will drop. This indicates that the train is not equally charged, and the drop in pressure is due to the air flowing from the head-end to the rear of the train faster than it is passing through the feed valves, and to prevent the head brakes from applying, due to an overcharge, make one or more "kick-off" movements, with the brake valve between running and release positions.

It should be known that the train is fully charged before making the brake application. By so doing it will often show effective brakes where more haste would not, and possibly cause unnecessary switching out of cars in order to obtain the required percentage. When the brakes are fully charged and test is to be made, a continuous service application of 25 pounds reduction should be made and brakes held applied until inspected.

RELEASING LONG TRAINS

In releasing the brakes on long trains, first, allow the brake valve handle to remain in release position for five seconds, then return to running position for five seconds; then make a second movement to release position for five seconds, after which return the brake valve handle to running position, remaining there until the brake pipe pressure drops below the adjustment of the feed valve; then make one or two "kick-off" movements between running and release positions.

Second, move the brake valve handle to release position, allowing it to remain there for 15 seconds, then return to running position for 10 seconds or until the brake pipe pressure drops below the adjustment of the feed valves, then make one or two "kick-off" movements between running and release positions. The same methods of releasing applies to brake applications on the road as well as to terminal tests.

STARTING

To avoid a break-in-two when starting the train, the throttle should not be opened until a sufficient time has been allowed for the brakes to fully release, and not less than one minute should be considered.

In starting, keep the train at a slow uniform speed so that the trainmen or inspectors can look the train over as it is passing by, to see that there are no brakes that have failed to release.

STOPPING TRAINS

When approaching a point where a stop is to be made, the engineer should gradually close the throttle. allow time for the train to bunch against the engine before the application is started. The make-up of the train, speed, time element, conditions of slack, whether in or out, governs the handling of the brakes. If the train consists of all loads, and is bunched, when brake application is started, a heavy service reduction could be made, without causing any ill effects. However, with the same train stretched, a heavy service application would cause a sudden bunching of the train on account of the head brakes applying in advance of those in the rear. The amount of shock would depend on the speed at the time the brakes were applied. When the speed is low the brake shoe frictions is high, hence the greater shock. Therefore, the engineer must always bear in mind that the speed, time element, and slack, whether in or out, governs the amount of the reduction. If the speed is low and the engineer is in doubt as to the condition of the slack, it would be advisable for him to gradually bunch the train with a light application, and before making a further reduction to increase the application, should wait until the slack of the train has had time to adjust itself.

In making stops with this same train from high speeds, the possibility of driving wheels sliding is present when nearing the final point of the stop. To avoid this, apply sand to the rail, commencing at a point eight or ten car lengths from the stopping point. The liability of driving wheels sliding is due to a higher braking power on the engine than on the cars.

TRAINS CONSISTING OF ALL EMPTIES

The handling of brakes with a train of this make-up is practically the same as with a loaded train, providing the speed, time element, and slack conditions are the same, except that the engine brake percentage is oftentimes found to be lower than the cars.

Therefore, the engine has a tendency to run out just before the stop is completed. To avoid this, a further service reduction should be made at about 50 feet from the point of the stop, and the brake pipe air should be exhausting from the brake valve when the stop is completed. The object of this is to start the slack in at a time too late for it to run out again before the stop is made.

In making stops with empties behind loads, if the train is bunched and the train is moving at a speed of 20 or more miles per hour, a service reduction of a sufficient amount should be made to apply the brakes on the whole length of the train. This reduction will no doubt cause the train to stretch when brakes apply on the rear, but as the speed is high there will be no bad results, merely a hard pull or stretching effect. This reduction combined with the brake pipe leakage, would no doubt stop the train at the point intended, but to avoid the hard stretching effect that is present with trains of this make-up, a further service reduction should be started at a point about 50 feet from the final point of stop. The object being the same as explained in the foregoing.

BACKING OFF TRAINS

In backing trains off on sidings or across the road, the action of the slack is the reverse from stopping. Therefore, the handling of the engine and brakes must be changed.

There are two methods that can be used for this movement, either of which will prevent the sudden change in slack and the possibility of damage.

First method.—After getting the train started, use steam lighter at first, then heavier, as the brake application is made. At the same time keep the engine brake from applying by holding the Independent Brake Valve in release position. The use of steam will have a tendency to keep the train bunched. By keeping the engine brake from applying has a tendency to offset the early effect of the head brakes over those on the rear.

Second method.—After getting the train moving with speed enough so that it will run into clear, close off steam gradually and allow slack to stretch, after which apply the engine brakes lightly; then make a service reduction and at the same time keep engine brake from applying by holding the Independent Brake Valve in release position.

RELEASING BRAKES AT SLOW SPEED

At just what speed brakes can be released without causing damage depends on how hard they are applied. The amount of main reservoir pressure and volume, whether slack is in or out, the length of train, road condition, such as sags, humps, and curves—no recommendations can be made to cover these conditions. The engineer should, however, take no chances—it is better to stop.

RELEASING BRAKES AFTER A LIGHT REDUCTION

One of the hardest brakes to release is one that is applied with a light application from standard pressures; the high amount of air remaining in the auxiliary makes the triple piston and slide valve harder to move to release. The lesser the difference between the brake pipe and main reservoir pressures, causes a more gradual flow into the brake pipe, resulting in a slow rise in its pressure.

Furthermore, in trying to get this to the rear after a light application, the head brakes are liable to be overcharged above the adjustment of the feed valve, causing some of them to reapply and stick.

In all cases where brakes are dragging, due to an overcharge and reapplication, brought about by a light reduction, where it has not been possible to make a sufficiently heavy reduction to prevent this, build up the pressure in the brake pipe about ten or twelve pounds, by adjusting the double pressure feed valve.

The feed valve should be readjusted to the standard pressure at the first opportunity.

CUTTING OUT BRAKES

In marshaling freight trains there must be at least three fully equipped air-brake cars coupled together next to the engine with brakes in perfect operation, which may be followed by not more than two cars in a series that are only piped for air, this course to be repeated until the full complement of cars has been assembled in a train. Under no circumstances should a car with defective air-brake, or one only piped for it, be placed next to the engine in any train, or more than two cars only piped, or one car with air-brake inoperative and one car piped, be placed together in any part of a train.

DOUBLE HEADING

When two or more locomotives are coupled in the same train the air hose should be coupled and the brakes tested and operated from the leading locomotive. For this purpose the cut-out cock in the brake pipe just below the engineer's brake valve, on all but leading locomotives, should be closed, air pumps kept running, brake-valve handle in running position, and the maximum pressure maintained.

In case of accident or disregard of signals by leading engineman, the engineman on the second engine can obtain control of the train by opening the cut-out cock and going to emergency position with brake-valve handle.

After a reduction to apply brakes in any class of service, brake valve handle must not be placed in release position until air ceases to discharge at brake pipe exhaust.

TERMINAL BRAKE TESTING

Passenger Trains

Testing passenger trains made up at terminals, the inspector should make an examination for leaks, with not less than 40 pounds pressure in the brake pipe.

When the brake pipe is fully charged, this will be indicated by the stopping of the pump on the locomotive, the engineer should make a 25-pound service reduction and move the brake valve handle to lap position until signaled to release.

After it is ascertained that each brake, including engine and tender, are applied, the engineman should then be signaled to release the brakes, and the brake on each car, tender and engine should be examined to see that each has released.

These tests should be repeated after every change in the make-up of trains, or when the air-brake apparatus is in any way disturbed from its condition when last tested.

The signal to be given always from the forward end of the train. The signal to release the brakes will be given from the rear car of the train to show that the whistle connections have been properly made.

In the absence of the air signal, the hand or lantern signal should be used, and the signal to apply brakes is to be given from the head end of the train; the signal to release brakes shall be given from the rear end of the train, as per rules of the road.

Passenger trains should have all brakes working before leaving the terminal. Eighty-five per cent. is allowable on freight trains as a minimum.

PASSENGER TRAIN STOPS

In making stops with passenger trains with more than 10 cars, the stop should be made with a two-service application; the first application should reduce the speed to about 12 or 15 miles per hour, releasing at a sufficient distance to insure all brakes will be properly released, and then returning brake-valve handle to running position. This will allow the brake pipe and auxiliary pressure to equalize. Then make a light service application holding this application on until the train comes to a full stop.

To insure a proper release do not place the brake valve in full release position until a further reduction of at least ten pounds is made in the brake pipe pressure. This will insure a proper release of the train brakes.

STOPS WITH SHORT PASSENGER TRAINS

In making stops with passenger trains 10 cars or less, except spot stops at water cranes, coal chutes, etc., the brakes should be released just before coming to a stop to avoid the recoil of the cars.

The method of supporting brake beams on passenger cars has quite an influence on making the stop smooth. For example—the old types of cars will often have outside hung brake beams, while the later types will be hung inside or between the wheels.

When making stops with the outside hung brake beams, there is a tendency to lift the truck frame in back and pull it down in front; this causes considerable recoil to the car when the brake is held on until a full stop is made.

The inside hung types will assist in steadying the truck because one wheel tends to lift the truck and the other to pull it down, but the lever formed by the beam support is much less and the tendency to move the truck is opposite to the direction in which the car is moving.

OVERCHARGING EN ROUTE

The feed valve having an adjustment of 70 or 110 pounds pressure, any excess above this in the brake pipe leakage will cause a reduction. Should the brake pipe be overcharged between stations, carry the brake valve in full release until the next stop is made; then reduce the pressure below its adjustment. This will prevent brakes creeping in and delay.

SERVICE APPLICATION

In making service applications of the brakes, the first reduction should not be less than seven pounds. Subsequent reductions at proper intervals can be made to increase the braking force sufficient to stop the train. One application includes the first reduction and all following reductions until brakes are again fully released.

Twenty-five pounds brake pipe reduction is the maximum amount that should be made in service application; any further reduction is a waste of air.

With the high speed brake, the auxiliary reservoir pressure will pass to the atmosphere through the high speed reducing valve, when a reduction below 25 pounds is made.

If it is found that there is a tendency for the train to surge, i. e., run into the locomotive, or a pull back, as is often observed when using mixed air brake equipment, it will be found advantageous to make an application strong enough to get all brakes while working steam; this will generally keep the train in a stretched condition, preventing slack action; the throttle should then be shut off and the train brought to stop as usual.

The split reduction is used also to prevent slack action when steam is shut off. For example—make a 7-pound reduction, pulling the slack in the train lightly (when a 10-pound reduction is required), and later follow up with a 3-pound reduction. This plan will hold the slack more uniformly than the full 10-pound continuous reduction.

THE RUNNING TEST

Enginemen on passenger train after leaving a terminal, or any point where the make-up of their train has been changed, should, as soon after starting as speed of train will permit, apply the air brake sufficiently to know that it is in good working order throughout the entire train.

Generally it is necessary to get the train going at about 20 miles per hour with modern steel equipment, and make at least 10 pounds reduction in the brake pipe pressure, having in mind the necessary difference in pressure which must be made between the auxiliary and brake pipe in order to get a proper application and release. A further reason for the recommendation of a 20-mile-per-hour speed is, for example, a 10-pound reduction will not stall the train and if, therefore, a test of 10 miles per hour under the above circumstances it might. It is well to remember that there are two factors roughly here; one is the force of the train and the other the brake shoe friction, the former being four times as much at 20 miles per hour as at 10 miles per hour. While the friction between the brake shoes and wheels at these speeds will be 24 per cent. at 10 miles per hour and 10 per cent. at 20, very nearly.

Steam should not be shut off when making a running test. With the E. T. brake equipment the Independent Brake Valve should be held in full release position in order to show the actual effect the brake has on the cars, and in case of a crossover of the signal line to the brake pipe will at once disclose this situation because no brake force will be had.

HANDLING THE P. C. EQUIPMENT

An emergency application will be obtained with the P. C. equipment if the service reduction of brake pipe pressure be continued below 60 pounds when carrying 110 pounds pressure, or below 35 pounds with 70 pounds brake pipe pressure.

The P. C. equipment equalizes higher than the old P. M., and more time should be given to all the release after an emergency application.

TAKING IN CARS EN ROUTE

When taking cars into passenger trains on the road, air hose should be properly coupled and angle cocks all opened except one on rear. The engineman should then place the brake valve in release position and allow it to remain there 15 or 20 seconds, then bring handle to service position and allow it to remain in that position until signaled to release. This plan causes the reservoir to charge on the rear cars until the brake pipe pressure is pulled down below the pressure obtained. For example—by placing the brake valve in full release, the pressure is brought considerably higher in the brake pipe, and when the angle cock is opened, this pressure passes to the auxiliary reservoir of the car. If the engineer has started a reduction at the brake valve, the air will continue to feed into the reservoir until the brake pipe of the car and auxiliary equalize, and then by the continued reduction the pressure is made less on the plain side of the triple piston; the auxiliary pressure forces the piston over and a brake application results. This scheme will save several minutes' delay and is very convenient, especially on local trains having cars to be picked up along the line of road.

AIR PRESSURES

While there is no hard and fast rule the standard air pressures are for the ordinary quick action brake, 70 pounds brake pipe and 90 pounds in main reservoir, except where the duplex governor is used, when the low pressure governor head will be set for 90 pounds and high pressure governor head for 130 pounds for the high speed brake.

HOLDING PASSENGER TRAINS ON DOWN GRADES

On down grades passenger trains should be controlled to a safe speed, and advantage must be taken of "let ups and curves" in grade to recharge even though the pressure in brake pipe has been reduced to only a few pounds. Keep the brake pipe pressure as near the maximum as possible. Before releasing the brakes be sure that the speed of train has been reduced and that there is ample time to recharge the auxiliary reservoirs to the maximum pressure before commencing another application.

BROKEN BRAKE PIPE

When a passenger car brake pipe is broken in service and away from a terminal point, the air-brake hose on adjacent cars can be crossed to signal hose on the car with broken pipe. Car discharge valve should be cut out. In such a case the air signal can only be used on the cars ahead.

BRAKES APPLYING FROM CAUSE UNKNOWN

Enginemen should shut off steam and place brake-valve handle in lap position immediately upon feeling brakes apply from any unknown cause; in case train has broken in two, hose burst, or conductor's valve opened, the pressure in main reservoir will be maintained for releasing brakes and recharging as soon as may be necessary. In cases of break-in-two, as soon as the angle cock is closed at the rear of the section to which the locomotive is attached, and signal given to back up, the handle of the engineer's valve should be placed in full release position only long enough to release the brakes; it is not then desirable to fully recharge the auxiliary reservoirs. In case train is stopped from a bursted hose, the brake-valve handle should be placed momentarily at short intervals of time in release position to assist trainmen in finding defective hose.

EMERGENCY FOLLOWING A SERVICE APPLICATION

In case of emergency, even though the reduction be 25 pounds in the brake pipe pressure, the handle of the brake valve should be placed in emergency position and allowed to remain there until train is stopped.

The use of sand increases the retarding power of brakes considerably, and should always be used in cases of emergency. In service stops when the rail is bad, sand should be used in making stops and applied to the rail in train length before brake application is commenced.

SUMMARY

Many accidents resulting from oversight are preventable. The following suggestions are offered as a digest of the preceding pages in this regard:

Watch the air-gauge.

Do not sacrifice safety in the interest of time; be sure that the air brakes are in proper working order before starting.

Insist on having full braking power; the chance taken will ultimately be rewarded for his acts.

If the air brakes are applied suddenly from any unknown cause, shut off steam at once, and place brake valve handle in lap position until the train is stopped.

If running a freight train on double track, protect against trains moving in the opposite direction, especially at night; there may be a broken wheel journal or truck frame in your train causing an obstruction on the opposite track.

Apply the brakes to run the slack slowly, and after bunching the train endeavor to keep it so while the brakes remain applied.

Shut the throttle gradually; remember the resistance offered by the engine will often run in the slack on a long passenger train with considerable shock.

Avoid quick applications, except in cases of emergency.

If a car equipped with a signal line does not release, don't let the trainmen bleed it off, but make a full service reduction of 25 pounds, then release the brake. They might have the air signal line crossed over to the brake pipe. Should the car not release, investigate the cause; perhaps the retainer is turned up. There may be a heavy leak in the brake pipe ahead of the car.

Have all leaks stopped; remember the air pump is the vital part of the brake system.

Economy in the use of air contributes to safety in maintaining the ability of the pump to replace that used; carry maximum brake pipe pressure if possible.

On grades, use the cycle method of braking. You will always have in reserve a good quantity of air for a quick stop if necessary.

If a brake does not apply in a service application it should not be cut out; it may work in an emergency application.

When conditions are favorable, a two-application stop in passenger service is much better than a single application.

The conductor and engineer are equally responsible for the condition of the brakes in the train.

Do not leave the terminal until you have the proper percentage. The rules require it; the law makes it mandatory.

THE AUTOMATIC AND STRAIGHT AIR BRAKE

One of the most sensitive devices for detecting pressure changes is by means of a diaphragm. It is largely used in experiments with sound.

This diaphragm principle is used with the new automatic and straight air brake. The advantages will be summarized in the following:

GENERAL DESCRIPTION

The equipment consists of a triple valve, an emergency (auxiliary) reservoir and a brake pipe reservoir. The brake pipe and brake pipe reservoir supply service braking pressure. The emergency (auxiliary) reservoir is used only to release the brakes and for emergency.

The use of diaphragms produce positive and effective operation of the triple valve. These diaphragms directly operate a pilot valve, which in turn operates the main pistons and side valves by creating differentials of pressure on the operating pistons greatly in excess of that required to overcome the maximum frictional resistance of the slide valves.

The triple valve cannot operate to lap position until, by means of the diaphragms, a necessary balance for a given reduction has taken place between the brake pipe, emergency (auxiliary) reservoir and brake cylinder, which predetermines the result in brake cylinder pressure. As a result the brake cylinder pressure for a given brake pipe reduction is practically uniform throughout a train regardless of brake cylinder leaks or variations in piston travel.

With the diaphragms the A. S. A. brake automatically compensates for, and maintains brake cylinder pressure against leakage.

Brake pipe leaks behind a closed angle cock cause the brakes to apply, as the diaphragms (which do not leak as is the case with pistons) control the movement of the operating valves.

The service position of the parts is dependent upon an equalization of pressure on both sides of the service piston, and not upon springs. In consequence, the service piston becomes inoperative and the main slide valve positively stops in service position, excepting when the brake pipe pressure reduction is at the rate of an emergency reduction.

The emergency (auxiliary) reservoir pressure is held fully charged during all service applications. In operating the triple valve in quick release the initial three-pound increase in the brake pipe pressure releases sufficient air from the emergency (auxiliary) reservoir to the brake pipe to produce a faster serial release than has heretofore been possible, permitting long trains to be released at low speeds without shock or damage.

Whenever the brake pipe pressure is reduced to a predetermined point of danger an emergency application automatically occurs.

Restored emergency (auxiliary) reservoir pressure for an emergency application is available at any time.

A. S. A. brakes operate in synchronism with the brakes now in service, and when so used improve their action.

The A. S. A. operates without the aid of electricity. It is purely a pneumatic brake.

A GENERAL STUDY OF THE MODERN LOCOMOTIVE

ADHESION—Adhesion is the grip or holding power, due to the weight of the engine on the rail.

Adhesion is the most important factor concerning the pulling power of the locomotive. It matters not how large the cylinders are, provided the adhesion sufficient to prevent slipping is present.

Whenever the power exerted by the cylinders exceeds the adhesion of the driving wheels against the rail, the engine will slip, so the hauling power really boils down to the available weight the engine can exert against the rail.

This weight in modern locomotives is taken from 4 to 4½ times the tractive power. That is, the factor of adhesion is from 4 to 4½; in other words, it is necessary to have 4 to 4½ times more weight on the drivers than is available for tractive power in order to have the engine haul the train properly.

Considering the foregoing description, the rail is assumed to be dry.

CLASSIFICATION OF LOCOMOTIVES

Whyte's System

The locomotive classification adopted by the American Locomotive Company is based on the representation by numerals of the number and arrangement of the wheels, commencing at the front. Thus 260 means a Mogul and 460 a Ten Wheel engine, the cypher denoting that no trailing truck is used.

Total weight is expressed in 1000 of pounds. Thus an Atlantic locomotive weighing 176,000 lbs. would be classified as a 442-176 type. If the engine is Compound the letter C should be substituted for the dash, thus 442 C 176. If equipped with Superheater, the letter S should be used—thus a Mallet locomotive having six pairs of drivers, with Superheater, would be classified: 0660 C S 334 if Compound, or 0660 S 334 if Simple. When tanks are used in place of separate Tender the letter T should be used in place of the dash. Thus a double end suburban locomotive with two wheeled leading truck, six drivers and six wheeled rear truck, weighing 214,000 lbs. would be a 266 T 214 type.

060	OOO	6-Wheel Switcher
080	OOOO	8-Wheel Switcher
0660	OOO OOO	Articulated
0662	OOO OOO o	Articulated
0880	OOOO OOOO	Articulated
010100	OOOOO OOOOO	Articulated
2440	o OO OO	Articulated
2660	o OOO OOO	Articulated
2880	o OOOO OOOO	Articulated
2442	o OO OO o	Articulated
2662	o OOO OOO o	Articulated
2882	o OOOO OOOO o	Articulated
210102	o OOOOO OOOOO o	Articulated
240	o OO	4-Coupled
260	o OOO	Mogul
280	o OOOO	Consolidation
2100	o OOOOO	Decapod
440	o o OO	8-Wheel
460	o oOOO	10-Wheel

480	o oOOOO	12-Wheel
042	OO o	4-Coupled and trailing
062	OOO o	6-Coupled and trailing
262	o OOO o	Prairie
282	o OOOO o	Mikado
2102	o OOOOO o	Santa Fe
442	o oOO o	Atlantic
462	o oOOO o	Pacific
482	o oOOOO o	Mountain

TRACTIVE POWER OF LOCOMOTIVES WITH BOILER PRESSURE OF 100 LB.

$$T = \frac{d^2 S .85 P}{W}$$

in which

T = tractive power;
d = diameter of cylinders in inches;
S = length of stroke in inches;
P = boiler pressure in pounds per sq. inch;
W = diameter of driving wheels in inches.

All the combinations of cylinder diameters, strokes and wheel diameters used in ordinary practice are included. These figures can be used for any boiler pressure by simply dividing the required tractive power by the ratio of the boiler pressure it is desired to use to 100 pounds pressure; as, for instance, 2 for 200 lb., 1.75 for 175 lb., and 1.6 for 160 lb. pressure.

In Europe as low as 60 per cent. of the boiler pressure is used instead of 85 per cent., the formula being

$$T = \frac{d^2 S .60 P}{W}$$

TRACTIVE POWER—COMPOUND ENGINES

$T =$ Tractive power (maximum).
$d =$ Diameter of H. P. cylinder.
$D =$ Diameter of L. P. cylinder.
$S =$ Stroke of piston.
$P =$ Boiler pressure.
$C =$ Constant (taken from the Table).
$W =$ Diameter of driving wheels.
$R =$ Ratio of L. P. to H. P. cylinder volume.

$$T_1 \text{ (Two-cylinder compound)} = \frac{D^2 S P C}{2 W}$$

$$T_2 \text{ (Four-cylinder compound)} = \frac{D^2 S P C}{W}$$

When $C = .52$ and $R = 2.5$

T_3 (Two-cylinder compound working simple)

$$= \frac{.85\ d^2SP}{W} = T_1 \times \frac{1.7}{CR} = 1.3T_1$$

T_4 (Four-cylinder compound working simple)

$$= \frac{(2 \times .85)d^2SP}{W} = T_2 \times \frac{1.7}{CR} = 1.3T_2$$

T_3 and T_4 give T when just moving. At slow speeds T working simple will exceed the power working compound by approximately 20 per cent.

For cylinder ratio of approximately 2.5 to 1, as ordinarily used, a constant of 0.52 may be considered as sufficiently accurate for estimates.

On superheater compound engines, in order to properly divide the work between the high and low pressure cylinders, the cut off in the low-pressure cylinder should be approximately 5 per cent. later than the cut off in the high-pressure cylinder for a cylinder ratio of 2.5 to 1. This difference in cut off should be reduced for higher cylinder ratios to 0 for a ratio of 2.75 to 1, and increased for lower cylinder ratios to approximately 10 per cent. for a ratio of 2.2 to 1.

TABLE OF CONSTANTS ("C")

Per Cent. Cut off H. P. Cylinder	Ratio of L. P. to H. P. Cylinder Volume						
	2.2	2.3	2.4	2.5	2.6	2.7	2.8
90	....	....	.571	.557	.542	.528	.513
89	....	....	.565	.550	.536	.521	.507
88	....	.573	.559	.543	.529	.515	.500
87	....	.567	.552	.537	.523	.509	.494
86	.575	.560	.546	.531	.517	.502	.489
85	.570	.555	.540	.526	.511	.497	.483
84	.564	.550	.534	.520	.506	.491	....
83	.559	.544	.529	.515	.500	.486	....
82	.553	.541	.524	.510	.496	....	....
81	.548	.534	.520	.505	.490	....	....
80	.543	.531	.515	.500	.486	....	....

BOILER CALCULATIONS

Locomotive boilers have their safe steam pressures computed in the following manner:

Let us assume the boiler has ¾ sheet and its largest ring is 72 inches, the tensile strength of the material is 55,000 pounds, the relative strength of the boiler seam to that of the solid plate is 85 per cent. Therefore, the formula is

$\frac{3}{4} \times \frac{55{,}000}{1} = 41{,}250$, which is the strength of the sheet; multiplying this by 85 per cent., the strength of the seam, we have 35,062; then dividing by ½ the diameter of the shell, which is 36 inches, giving us 979; this divided by the factor of safety, which is 4.5, or 4½, will give us 217 pounds, the safe working pressure. For example, take the thickness of the shell at its largest ring, multiply it by 55,000, the result times 85 per cent., and divide by ½ the diameter of the boiler, then by 4½, and read off the safe working pressure.

FACTOR OF SAFETY

Nearly every piece of material that enters into the construction of a locomotive has a factor of safety. The factor of safety is the ratio of the stress a metal is subjected to relative to that at which it would burst or break. For locomotive boilers we use a factor of safety of 4½ to 5, which simply means the bursting pressure is 4½ to 5 times the safe working pressure. For example, suppose a boiler has a safe working pressure of 220 pounds per square inch, the bursting pressure is 1100 pounds per square inch, we have $1100 \div 220 = 5$, the factor of safety. Therefore, when it is desired to determine the factor of safety, simply divide the steam pressure carried into the bursting pressure and the result is the factor of safety. For example, in the foregoing boiler increase steam pressure to 275, then $1100 \div 275$ gives a factor of safety of 4.

Another rule for determining the factor of safety is, take the tensile strength of the plate, which is generally assumed to be 55,000 pounds per square inch, and multiply the thickness of the plate, divide this sum by ½ the diameter of the boiler, multiplied by the steam pressure, this result to be multiplied by the efficiency of the longitudinal seam, which is 85 per cent. on modern locomotive boilers. Hence ¾ sheet, 55,000 tensile strength, 72-inch boiler at the largest ring, 200 pounds of steam. $\frac{3}{4} \times 55{,}000 \div 200 \times 36$ equals 5.73. Then 5.73×85 per cent., the joint efficiency, we have 4.87, the factor of safety.

Suppose the steam pressure in the above example was increased to 240 pounds, what would the factor of safety be?

$\frac{3}{4} \times 55{,}000 \div 240 \times 36 = 4.77$ about.

Then 4.77×85 per cent. $= 4.1$ about.

Generally a factor of safety of 4½ is used on a new locomotive.

BOILER SEAMS

The question is often asked, why is it that the girth or circumferential seams have but one or two rows of rivets while the lengthwise or longitudinal seams have four or even more rivets in them?

Girth seams need only one-half the strength to hold them since the surface to be held is that much less.

Example: Take a boiler having a 66 inch ring, ¾ sheet, and tensile strength of 55,000 pounds per square inch; the bursting pressure of this ring would be $\frac{3}{4} \times 55{,}000 \div 33$, or tensile strength times ¾ divided by ½ the diameter. Worked out $\frac{3}{4} \times 55{,}000 = 41{,}250$, and $41{,}250 \div 33 = 1{,}250$. That is, the strain necessary to break a solid ring without a joint would be 1,250 pounds per square inch. The total strain on the ring when it breaks will be the surface of the metal times the tensile strength, or briefly stated, $66 \times 3.1416 = 207.3$ inches of metal in circumference, and this times ¾ will give the surface in square inches; then multiplied by ¾ times 55,000 will show the total pressure causing the rupture. Worked out $207.3 \times \frac{3}{4} = 155.47$ square inches. Then this times the tensile strength $155.47 \times 55{,}000 = 8{,}550{,}850$ pounds. The pressure tending to separate the boiler lengthwise is the area of the head or tube sheet in square inches times the pressure per square inch. The area is 3,421; therefore, if we divide 3,421 into our total bursting pressure of the ring, which is 8,550,850, we will get the relative strength of the girth seam to that of the longitudinal. Worked out, $8{,}550{,}850 \div 3{,}421 = 2{,}500$, nearly, twice as strong as that of the longitudinal seam.

A very handy formula for girth seam stresses is: Take the radius of the boiler, which is ½ the diameter times the steam pressure, and divide by two times the thickness of the shell. In the foregoing 66 inch boiler in diameter or 33 inch radius, 200 pounds of steam ¾ shell $33 \times 200 \div 1\frac{1}{2} = 4{,}400$ stress on the seam in pounds per square inch.

Since the use of seams in locomotive boilers tend to cause a lower strength of material one would wonder why the cylindrical portion is not made in one piece instead of several rings connected together by means of rivets. The reason is, since one ring fits over the other it has a great stiffening effect on the barrel of the boiler and for that reason is desirable, however, these methods are not depended upon where the distance exceeds 10 feet between the joints. It is, of course, to be remembered that the tubes relieve the stress to a considerable amount on the girth seams since their holding power is about ¾ of their tensile strength.

STAYBOLTS

The maximum strain or tension allowed on a staybolt is taken at 5500 pounds per square inch; generally a pitch of 4 inches is maintained in locomotive practice. There is a very good rule, however, for computing the allowable load on a staybolt, as follows: Take the diameter of the narrowest portion of the staybolt, square it (the diameter) times .7854 and then multiply by the pitch times pitch and divide the result into 5500. For example, 15/16 staybolt smallest portion, 15/16 = area about .7 square inches, pitch of staybolt 4 inches; we have 4 × 4 = 16 square inches, and this times 7 gives us 11.2. Neglecting the surface taken out by the staybolt entering into the boiler plate our formula stands .7 × 16 — 11.2 and this divided into 5500 gives us 491 pounds, the safe working pressure on the staybolt.

Staybolt pitch or the safe working pressure allowed on the firebox can be had by the following rules (for pitch):

Take the thickness of the sheet in sixteenths, multiplied by itself and this times 112; then divide this sum by the boiler pressure carried, which gives the square inches; then extract the square root for the pitch in inches. Example: ⅜ sheet has 6 sixteenths, and this times six gives us 6 × 6 = 36; then 36 × 112 = 4032;

then dividing by 200 say for the pressure, gives us 20.16; then the square root of this is 4.42, or 4½ the pitch.

Then working backwards, we have a rule for determining the safe working pressure from the pitch of the bolts. Take the thickness in sixteenths, multiplied by itself or squared times 112, and divide by the pitch of the staybolt squared or multiplied by itself. Thus ⅜ sheet 6 sixteenths: 6 × 6 = 36 and 36 × 112 = 4032, and this divided by sixteen, which will represent the pitch squared, or 4 × 4, the pitch times pitch; we now have 4032 ÷ 16 = 252 pounds per square inch, the safe working pressure on this firebox construction, i. e., the thickness of the firebox plate and staybolt pitch, while other stated rules had reference to the strength, load and pitch of the staybolt only.

These rules hold good on fireboxes having plates up to 7/16 inches in thickness, but above this use the constant 120 instead of 112. Example: ½ inch 8 sixteenths; 8 × 8 = 64 × 120 = 7680, and assume the pitch to be 4 inches, we have 4 × 4 = 16, and 7680 ÷ 16 gives us 480 pounds per square inch safe working pressure. It will be seen from the foregoing the reason why thin plates are often used in firebox construction; there is a large margin of safety here.

In the foregoing pages we have taken up the safe working pressure of boilers, their seams and staying of flat surfaces. Our next subject will be the dome.

Steam domes are attached to the boiler by flanging the base of the dome or by the use of a collar. The essential thing to remember is the amount of material which is cut away from the boiler shell to provide a means of getting into the boiler, causes a reduction in its strength, which must be compensated for by a reinforcing liner or other means. The practice at present is to use a liner inside the section of the boiler having the large hole cut in it for the purpose of reinforcing and bringing its factor of safety up to that of the other portions of the boiler. The formula used to determine the efficiency of the dome is: Take the net area of the dome base liner and sheet and divide by the net area between the circumferential seams. Or briefly stated, the thickness of dome base liner and sheet or main portion of boiler shell multiplied by its length and this sum divided by length times thickness of the material between the circumferential seams before it was cut away. For the area of the dome collar include the horizontal flange and curve up to a vertical tangent, i. e., when there is no curve or the metal becomes straight again.

When computing the area of the sheet after the metal is cut away the surface of the rivet holes should be subtracted from the metal in addition to the amount of metal removed from the boiler shell. Then, to find the efficiency, divide the area of the solid sheet into the area of the plate after the removal of the material and read off the result in per cent.

Worked out in detail we have, say ¾ sheet for boiler shell, ¾ liner and ¾ dome base. The distance between the circumferential seams is 78 inches, the liner is 70 inches, the dome collar is 8 inches for surface. We have 78 × ¾ = 58½ square inches; 70 × ¾ = 52½ square inches.

Suppose the hole in the boiler shell is 30 square inches and the area taken out by the rivets is 4 inches more, or 34 inches all told, the flange or dome base is 6 square inches. We now have 56¾ — 34 = 22¾, i. e., solid sheet less the hole in boiler and area of rivet holes. The dome base is 6 inches. We now have

$$22\tfrac{3}{4} + 34 + 6 = 62\tfrac{3}{4}$$

The area of the solid plate was 56¾ square inches so that we now have

62¾ or 62.75 ÷ 56¾, giving us 110% or a strength of 10% above the solid sheet.

Next to get the factor of safety we must first have the stress to the centre line of the dome. For this we have boiler pressure times inside diameter of boiler shell, i. e., the course on which the dome sets. Then divide this sum by two times the thickness of the sheet multiplied by the efficiency derived from the foregoing problem. Working this out, assume a 72-inch course and a ¾ sheet, the efficiency being 110% and boiler pressure at 200 pounds per square inch, we have worked out

$$\frac{200 \times 72}{2 \times \frac{3}{4} \times 1.10} = 8727$$

Now for the factor of safety we have tensile strength of material divided by the foregoing stress to centre line of the dome. The material being ¾ and the standard tensile strength we have ¾ × 55,000 = 41,250, and this divided by 8,721, the stress through centre line of the dome, or 41,250 ÷ 8,727, or 4.7, the factor of safety.

It is necessary to ascertain this factor of safety in dome construction, because the factor taken in computing the safe working pressure of a boiler must always be equal to or greater than 4½ on new construction and should not in any case be below 4.

BACKHEAD BRACING

For backhead bracing the area to be stayed by the backhead longitudinal braces is obtained as follows:

A line is taken one inch below the point from which the radius of the back head flange is struck, and also to two inches from the centre of the nearest row of staybolts. The area thus enclosed is considered as being supported by the backhead longitudinal braces. The load on the total number of braces is equal to this area multiplied by the boiler pressure. The braces should be as evenly distributed as possible and the load on each brace is considered as equal to the total load divided by the total number of braces.

The feet for braces to back head and front tube sheet should be distributed so as not to concentrate the stress on any one section. Preferably a portion of the brace feet on the second course from the back head or front tube sheet. Usually the diagonal should be within 10 or 12 degrees. The increased stress due to the diagonal of bracing need not be considered when the angle does not exceed 15 degrees.

In figuring the longitudinal braces, the fibre stress of all parts in tension, the pins in shear and the rivets in sheer or tension are considered; also the bearing value of the pins and brace eyes and rivets. While the tee iron riveted to the back head adds something to the bracing, this is not considered. This method is based on supporting the total load by the longitulinal braces.

When gusset braces are used, divide the area of the back head braced into sections supported by each gusset. The fibre stress in each gusset is obtained by dividing the load on each separate section by the least area of that gusset.

FRONT TUBE SHEET BRACING

Braced area for front tube sheet to extend three and one-half inches from outside of flange, and two inches from outside of nearest tubes. Compute area to vertical centre line of boiler (that is, each side separately) and deduct one-eighth area of outside diameter of dry pipe ring when there is sufficient space for crowfoot below the tube sheet ring. Deduct one-sixth area of outside diameter of dry pipe ring when there is not sufficient space for crowfoot.

Concentrate braces as much as possible at lower ends of tees and around dry pipe ring.

SHEARING STRESS ON RIVETS

The shearing stress on rivets in pounds per square inch can be calculated by using the following formula:

$$S = \frac{D \times P \times K}{2 \times N \times A}$$

S = Shearing stress on rivets in pounds per square inch.

D = Inside diameter of boiler.

P = Working pressure.

K = Pitch of rivets in inches.

N = Number of rivets to be sheared per pitch length of seam.
A = Area of rivet.

TENSION ON NET SECTION OF PLATE

The tension on net section of plate in pounds per square inch may be calculated by the following formula:

$$T = \frac{P = D}{2 \times E \times A}$$

T = Tension or net section in pounds per square inch.
P = Working pressure.
E = Efficiency of seam.
A = Area of solid plate per lineal inch.
D = Maximum inside diameter of any course of the boiler shell.

SATURATED STEAM TEMPERATURE FORMULA

For a very convenient method in determining the temperature of steam in degrees Fahrenheit from gauge pressure, take the square root of the gauge pressure, multiply it (the square root) by 14, then subtract 100 from the pressure and divide this second operation by 11, add 198 to this and read off the result in degrees Fahrenheit.

Example: Take the steam pressure at 200 pounds gauge. The square root of 200 is 14.2 nearly; then we have:

$$14.2 \times 14 - (200 - 100) \div 11 + 198$$

This worked out gives us for the first part:

14.2
14

568
142

198.8

Now working out the second portion of our example we have:

200 — 100 equals 100

100 divided by 11 equals 9 1/11 or 9.09, expressed in a decimal; now subtracting this from the first sum we have:

198.8
9.09

189.7

Then adding 198 to this we have:

189.7 nearly
198

387.7 Deg. Fahrenheit

PISTON SPEED AND REVOLUTIONS PER MINUTE

A very easy method in determining the revolutions of driving wheels per minute can be had by multiplying the miles per hour the locomotive is running by 28 and dividing by the diameter of the driving wheel in feet.

This worked out would be, for example, a 72-inch driving wheel or 6 feet in diameter.

Speed say, for example, 60 miles per hour,

$$\begin{array}{c} \text{We have } 60 \times 28 \text{ equals } 280 \\ \hline 6 \end{array}$$

Worked out in detail:

$$\begin{array}{r} 28 \\ 60 \\ \hline 1680 \end{array}$$

Then this sum divided by 6, we have:

6)1680(280 revolutions per minute.

This formula is used also in determining piston speed by simply multiplying the revolutions of the wheel by twice the stroke in feet. For example, take a 26 inch stroke, 280 revolutions per minute.

The stroke in feet will be 2 × 26 equals 52 inches; this divided by 12 will give the feet 52, divided by 12 equals 4⅓; then by the revolutions: 280 × 4⅓ equals 1,213 feet per minute.

In assigning locomotives to fast trains it is essential that the work or speed at which the locomotive is run should not be more than that which would produce an excess of 1100 feet of piston speed per minute. That is for good economical operation.

TRAIN RESISTANCE AND TONNAGE RATING

Some general conclusions upon train resistance are as follows:

The resistance per ton of freight cars decreases greatly with the increase of weight and capacity; therefore it is economical to use fully loaded large capacity cars. An empty or partially loaded car has a much greater resistance per ton than one fully loaded.

The condition of track, alignment—both in vertical and horizontal planes—stiffness of rails, etc., materially affect train resistance because much energy is expended in hauling cars on poor track on account of dampened oscillations causing absorption of energy, and concussions which principally increase flange friction.

The decrease in resistance on level, straight track of cars of 50 tons capacity (total about 72 tons) or greater, is of great significance in estimating tonnage ratings on low grade roads. This decrease in resistance becomes of relatively less importance with increase of grade.

It has been observed frequently that the resistance of American freight cars is practically the same between the limits of 5 and 25 miles per hour.

Journal friction is greatest at starting, then rapidly decreasing and gradually reaching its minimum somewhere around 15 to 20 miles per hour, and afterwards remaining constant or slowly increasing. This condition is influenced materially by weather conditions.

Journal friction with good lubrication within the limits of railroad pressures probably varies inversely as the square root of the pressure.

With large capacity loaded cars at freight car speed on good stiff track, journal friction forms a large percentage of freight car resistance.

Decrease in temperature causes journal friction to increase. Allowance from full tonnage must be made for cold weather and high winds.

Grade resistance is equal to 20 pounds per ton (2,000 lbs.) for each one per cent. It is unaffected by weather conditions, but the length of grade, if operated by reducing velocity, must be considered.

Resistance per degree of curvature in pounds per ton should not be taken at less than 0.08 for standard gauge, and 0.06 for narrow gauges. For locomotives it varies materially with the length of rigid wheel base.

Engine friction should be considered apart from the resistance of cars and estimated from the weight on drivers. The tender and part of the engine supported on trucks or trailing wheels may be taken at the same resistance per ton as cars of approximate weight.

Engine friction may be approximated by multiplying the weight on drivers in tons by 25 pounds.

The maximum horse power of a saturated steam locomotive is usually reached at about 700 feet piston speed per minute; constant horse power at 700 to 1,000 feet piston speed, decreasing slightly at higher speeds with the decrease in the efficiency of the engine. For superheated steam locomotives the maximum horse power is usually reached at 1,000 feet piston speed per minute, then constant horse power up to its limitations.

The resistance of passenger cars has usually been overestimated; but the decrease in available power of a locomotive at high speeds, due to the decrease in mean effective pressure in combination with the energy absorbed in moving the engine and tender generally has been underestimated.

INDEX

HEAT AND STEAM

Heat 13
" Transfer of 13
" Radiation of 14
" Conduction of 14
" Convection 14
" Rate of transfer of 14
" Definition of 10
" Unit of 10
" B T U — definition of . . . 10
" Latent — definition of . . . 12
" Sensible — definition of . . . 12
" and work — examples of . . . 13
Steam 12
" Saturated — definition of . . 12
" Superheated — definition of . . 12
" Examples of — its formation . . 15-16
" Temperature at atmospheric pressure 14
" Relative — temperature to the water 15
" Heat required to change pressure . 20
" Advantage of high pressure . . 20

COMBUSTION

Combustion 21
" The B T U 21
" chemical symbols used in . . 21
" coal burned to CO^2 . . . 21
" Definition of 21

Combustion 21
" Yield in B T U Co. — CO^2 . . 21
" Quality of 21
" Modern ideas of . . . 22
" Coal 25
Combustion and Firing 25
" " wetting coal . . 25
" " air requirements for 26
" " starting out . . 27
" " best method of . 27
" " smoke prevention of 28
" " importance of high temperature . 28
" " shaking grates . . 29
" " engines slipping . 29
" " summary on . . 30-31
" " advantage of large grate area . . 33
" " drumming . . 32
" " honeycomb . . 32
" " how fuel may be wasted . . 33

THE BRICK ARCH

Brick Arch, The 38
" " " Purpose of . . . 38-39-40
" " " Location of . . . 39
" " " Flue protection . . 42
" " " and Honeycomb . . 43
" " " Tubes 44
" " " Evaporating power of tubes 44

LOCOMOTIVE BOILERS

Crown Bar Type — description of . . 45-46

Radial Stay Type — description of . . 46-47
Wooten Type — description of . . 48-49
Belpair Type 49-50-51
Stays — Location of 51
Dome — Location of 51
“ Cap 53
Firebox Sheets — Thickness of . . 52
Combustion Chamber — Advantage of . 53
Grates, Method of setting . . . 53
Expansion, Provision for . . . 53
Turret — Location and duty of . . 53
Blower, The 53
Firebox, Staying — Reason for . . 54
Staybolts, Rigid 54
“ Holes in same 54
“ Breakage of 55
“ Test for broken 55
“ Flexible advantage of . . 56
“ Flexible Radial Stay . . . 57
“ Flexible — description of . . 56-57
Tubes — Boiler 57
“ “ Setting 58
“ “ Beading 58
“ “ Welding in . . . 58-59
Locomotive Boilers — In General . . 59
“ “ Material in . . . 59
“ “ Firebox — material in . 59
“ “ Steam — domes . . 60
“ “ Size of the . . 60
“ “ Firebox — water legs . 61
“ “ Steam space in . . 61

Locomotive Boilers — In General . . 59
" " Value of direct heating surface . . . 61
" " Tube — length . . 62
" " Superheating surface ratio 62
" " Grate area . . . 62-63
" " Rate of evaporation . 63
" " Ashpan . . . 64
" " Ashpan — minimum air opening . . . 64
" " Size of grate openings . 64
" " Water . . . 64
" " Water — in general . 65
" " Scale and pitting . . 65
" " Grooving . . . 65
" " Priming and foaming . 66
" " Foaming — example of 66-67
" " Horsepower — definition of . . . 11
" " and cylinder horsepower 61
" " Calculations . . 505

SUPERHEAT LOCOMOTIVES . . 68
Superheated Steam — relative volume of . 71
Superheater — Principle of the . . 68
" Purpose of the 68
" and Cylinder Condensation . 70-73
" Comparative tests of — savings with 70
" Engine correctly operated . . 72
" General description of . . 73

Superheater 68
" Header 73
" Units — location of 74
" Flues — size of . . . 75
" Flues — temperature of gases passing through . . . 75
" Raise in temperature as a result of 75
" Damper arrangement . . 76
" Operation of the . . . 92
" High water in 78-92
" Engines steaming hard . . 78
" Engines drifting . . . 79
" Engines — lubrication of . . 79
" Engines firing 79
" Maintenance and repairs . . 80
" Tests of 81
" Leaking units 81
" Cylinder and valve rings used with 82
" Fit of valve and cylinder rings used with 82-83
" Importance of clean flues . . 93
" Method of cleaning flues . . 94
" Clamp bolts 94
" Unit bands and supports . . 95
" Front end air leaks . . . 97
" The Pyrometer 98
" The Pyrometer — Duties of . 100
" The Pyrometer — Operation of . 100
" The Pyrometer — Names of parts 102
" Dampers — maintenance of . 83
" Dampers — construction of . 84
" Dampers — Operation of . . 84

Superheater Dampers — Improper installation of 25
“ Dampers — Link too long . . 85
“ Dampers — Link too short . 86
“ Dampers — Lost motion in . . 86
“ Dampers — taking up slack in . 87
Damper — Prevention of Freezing . . 88
“ Steam Pipe — size of . . . 88
“ Piston — tightness of . . . 89
“ Switch engine 90
“ What to do — maintaining the . 91
“ Lubrication 91
“ What not to do — maintaining the 91
Dampers — Summary on care of . . 91
LOCOMOTIVE BOILER APPLIANCES . 105
Injectors 105
“ Principal of operation . . . 105
“ How they should work . . . 106
“ Why water enters boiler . . 107
“ Classification 109
“ The “Sellers” 110
“ The “Sellers” Non-Lifting . . 112-114
“ The “Sellers” Operating Stand . 116
“ The “Sellers” Duplex Check Valve 118-119
“ The “Sellers” Combined Check and Stop Valve 119
“ The “Sellers” Feed Water Strainer 120
“ “Monitor” 122
“ “Simplex” 123
“ “Simplex” Non-Lifting . . . 126
“ “Simplex” Non-Lifting “A” and “B” 128
“ Applying 131

Injectors 105
" Failures 132
" Lifts but does not force water into the boiler 135
Hancock Inspirator Lifting Type . . 143
" " Operation of . . 144
" " Causes of Failures . 146
" " Non-Lifting . . . 148
Klinger Reflex Water Gauge . . . 139
Safety Valves — Consolidated . . 152
" " Richardson Adjusting Ring . 155
" " Free from scale . . . 155
" " The Ashton . . . 156
" " The Ashton M.M. . . 157
" " General Information . . 159
" " Humming 159
" " Setting 160
" " Change pop . . . 160
" " Seats 160
" " Springs 162
" " Setting Three . . . 162
Steam Gauges 163
" " Principle of 163
" " Ashton 163
" " Ashton Single Spring Gauge 164
" " Names of parts . . . 165
" " Ashton Lane . . . 165
" " Ashton Lane—names of parts 166
" " General Information . . 166
" " Connections 166
" " Siphons 168
" " Location of 167

Steam Gauges 163
" " Strained 167
" " Graduation 167
" " Dials 167
" " Tubes 167
" " Repairing and care . . 168
Mason Locomotive Reducing Valve . 169
Leslie Steam Heat Regulator, The . . 171
Throttle Valve, The Chambers . . 172

LOCOMOTIVE FRONT END APPLIANCES 175
Method used to create draft . . . 175
Power necessary to create draft . . 176
Mr. McFarland tests with . . . 176
Master Mechanics, The 177
Stack, Dimensions 177
Diaphragm and Draft Plate . . . 179
" Plate Location of . . . 179
" Plate Area under the . . . 180
Two Theories of the Operation . . 181
Mr. Coddington's tests 182
Types of Nozzles 183
Effect of Nozzle height 185
Rectangular Nozzle, The . . . 186
Testing stack pressure 187
Nozzle effect on fuel consumption . . 188
Testing front end temperature . . 189
The Turner front end 190
The extended front end 191
Method of determining nozzle size . . 191
Lining the Nozzle 192
Reducing the Nozzle 193
The Petticoat Pipe 192

Draft Inefficiency 193
Detecting air leaks 195
" steam leaks 195
Choked netting 197
Front end filling 197
Exhaust pipe or base 197
Effect of bridge in the exhaust pipe or base . . . . . 197-200 incl.
The Draft Gauge 200
" " " operation of . . . 200

LOCOMOTIVE VALVES AND VALVE GEARS

Foreword 204
D slide Valve, the 204
Lap, purpose of 204
Clearance, purpose of 204
" How measured 204
Lead 205
Cut Off 205
Port opening 205
Preadmission 205
Admission 205
Release 205
Compression 205
Stephenson Gear, The 205
" " Reversing the . . 207
" " Shortening cut off . 207
" " Link 208
" " Direct Rocker arm . 209
" " Indirect Rocker arm . 209
" " Lead of main valves . 210
" " Eccentric Location . 212

Stephenson Gear, The 205
" " In general 222
" " Rocker arm Types . 213
Main Valves Allen Richardson . . 213-214
" " The American Balanced . 215
" " The piston type . . . 216
Stream Line cylinder ports . . . 217
" " " " Advantage of 217
" " " " Description of 217
Valves Inside admission 219
Valve Chest Universal 220-222
Cut Off Maximum 223
" " and eccentric Location . . 223
" " and Compression . . . 223
" " Port opening desirable . . 223
Valve travel, determining the . . . 224
Main Rod, Angularity of the . . . 224
" " " " " Effect on Steam Distribution 226
Causes for sounding out of square . . 226
Slack determining, amount of . . . 228
Setting Valves on the Stephenson . . 228
Dead center, locating the . . . 229-284
Port Marks, finding the 229
" " and Lead 230
Lead Equalizing the 230
Cut Off, Equalizing the 231
" " Range of 232
Valve travel 232
The Walschaert Gear 233
" " Simple forms . . . 234
" " Cut off diagrams 240-241-242-243

The Walschaert Gear 233
" " Explanation of . . . 245
" " Rules for changing length of rods 247
" " General arrangement 247-248-249-250
" " Setting The . . . 250-255
Variable lead 255
" " How obtained, example of . 256
" " Setting with . . . 257
" " How to tell Engines with . 258
Brake downs 259-260
Broken eccentric crank 260
" Suspension Link 260
" Radius Rod 260
" Combination lever . . . 261
" Valve stem 261-262
" Link block pin 261
Brake downs, short cuts with . . 262-265
Sounding out of square 265
Logy engines 266
Checking Valve setter 266
Valve gear defects and fuel consumption 267
Baker gear, The 267
" " " First application . . 268
" " " Description of . . 268
" " " Section inside—Admission 269
" " " Section outside—Admission 270
" " " Principle of operation . 271
" " " Cut off Diagrams . 272-275
" " " Explanation of diagrams 271-277
" " " Reversing the . . 277
" " " Mid gear position . 277

Baker Gear, The 267
" " " Difference inside and outside admission . 278
" " " Lap and Lead . . 278
" " " Lead, changing the . 278
" " " Rules 279
" " " Setting the . . . 279
" " " Correct cut off . . 279
" " " Setting, Recommended practice . . 280
" " " Trams 281
" " " Port marks . . 281
" " " Port holes . . . 281
" " " Dead centers . . 283
" " " Power Driven Rolls . 285
" " " Eccentric Crank Setting 285
" " " Valve rod and Eccentric Rod adjustment . 285
" " " Eccentric Crank and Main Pin . . . 289
Summary on valve setting . . . 289-290
Trailing 291
Breakdowns 293
" two classes 293
" summary on 294
Broken eccentric crank 293
" gear reach rod 294
" main reach rod 294
Southern Valve Gear, the . . . 296
" " " diagrams . . 298-299
" " " setting the . . 300
" " " breakdowns . . 303

Broken Radius bar 303
" " " hanger . . . 303
" Transmission yoke . . . 303
" Horizontal arm of bell crank . . 303
" auxiliary reach rod . . . 303
Ragonay Power Reverse gear . . . 305
" " " " operation of 305
" " " " care of the . 307
" " " " cylinder packing 307

LOCOMOTIVE RUNNING

Care of Locomotive Lubricators . . 308
Principle of the Lubricator . . . 308
The old style lubricator 311-312
Choke plugs 312
Lubricator Glasses — bullseye . . . 313
" The Nathan Type 166-F . . 314
" " " Booster pipe . . 315
" " " Names of parts . . 317
" " Detroit Bullseye . . 318
" " " Condenser . . 319
" " " Water Check Valve . 320
" " " General construction . 321
" " " Steam Chest choke plug 323
" " " Starting the . . 323
" " " setting feeds . . 324
" " " oil control valve . 325
" " " recommended practice 327
" " " before leaving terminal 327
" Care of the 328
" defects 329
" " stopped up feed nozzles . 329
" " stopped up choke plugs . 330

Lubricator Glasses — bullseye . . . 313
" " irregular feeding . . 330
" " loss of oil . . . 331
By-pass valves 332
" " " open 335
" " " closed 333
" " " broken — remedies for . 334-336
Vacuum Breaker, The Nathan . . . 336
" " Duties of 337
" " Open 338
" " Closed 339
Franklin Driving Box Lubricator, The . 340
Journal bearings — tender . . . 341
" Method of packing . . . 342
" Waste — quality used . . . 342
Working steam expansively . . . 342
Modern valve gears — effect on steam expansion 343
Starting the train 344
Getting over the hill 344
Locomotive boiler — care of the . . 345
Reporting work on the engine . . . 347
Locating blows 348
" " main valve . . . 348
" " cylinder packing . . 350
" " in by-pass valves . . 351
Testing for pounds 352-378
Why use the top quarter when testing . 352
Loose saddle key 352
Renewing rod bushings 353
Engines pounding — shut off . . . 353
" " " " determining the side . . 354

Setting up wedges 355
Wedges sticking 355
Franklin self-adjusting wedge . . . 355
Keying rods 355
" " key ahead of the pin . . 355
" " key behind the pin . . 356
Engines slipping 356
" " proper method of working . 356
" " two methods of handling . 357
" " applying sand . . . 357
Hard riding engines 357
" " " remedies . . . 358
" " " stuck wedges . . 358
" " " effect of counterbalances 359
" " " quarter slipped engines 359
" " " effect of trailer truck maintenance on . 360
Locomotive accidents or breakdowns . 360
Foreword 360
Suspension of weight — method of . . 361
Breakdowns by types of locomotives . 361
Spring rigging 361
" " equalization of 361
Transferring weight 362
" " overhung engines . 362
" " underhung engines . 363
" " reducing driving wheel load 363
" " with broken tires . 363
" " method of raising the engine up . . 363
Broken spring hanger overhung engines . 364
" main driving spring overhung engine 365

Broken main driving spring engine hung between the frame rails . . . 365
Broken main driving spring underhung engine 367
" Back driving spring or hanger overhung engine 367
Method used with Mogul consolidated or Micado types 368
Broken main journal overhung engine . 369
" " " underhung engine . 369
" Equalizer on overhung engines . 369
" Main tire — ten-wheel engines . 371
" " " " " " underhung 372
" Piston or piston rod . . . 372
" Side or parallel rods . . . 373
" " " " " preventing slipping 373
" Trailer truck spring or hanger — Atlantic type, Pacific type . . 374
" Main frames 375
" " " What to do with . . 375
" " " Examples of strains . 376
Handling dead engines 379
Compound Locomotive, The . . 380
" " Definition of . . 381
" " Balanced, The . . 381
" " Principle of the . . 381
" " Cylinder, proportions of 383-386
" " Advantages of . . 384
" " Steam consumption of . 384
" " Economy in . . 384
" " Disadvantaged of . 385
" " Principal systems . 385

The American 385
" " Intercepting valve . 389-393 incl.
" " By-pass valve . . . 393
" " Operating the . . . 387-388
" " Vacuum and relief valves . 394
" " Tests for blows in . . 395
" " Accidents — treatment of . 395
Simplex, System, The 395
" Intercepting valve . . . 396
" Operating the 401
Trailing Truck, The Alco . . . 401
" " " " Advantages of . 403
" " " " Centering springs 404
Electric Headlight, The 404
" " " General Electric Co. 404
" " " Operation of . 404
" " " Speed of . . 406
" " Compensating lamp loads . 406
" " Brake pole piece . . 406
" " Shunt coil . . . 406
" " Brushes 407
" " Bearings . . . 407
" " Lubrication of . . 408
" " Adjustment . . . 408
" " Adjustment voltage . . 409
" " Names of parts . . 412

THE AIR BRAKE

Foreword 413
Standard pressures 494
Triple Valve, principle of . . . 413-420
Quick Action — triple valve . . . 421

Air Compressors 422
“ “ Principle of differential piston 422-424
“ “ Names of parts . . . 424
“ “ Standard sizes . . . 426
“ “ Operation . . . 426
“ “ “ Steam end . . 426
“ “ “ Air end . . . 430
“ “ “ Starting and running 431
“ “ Lubricating steam cylinder 432
“ “ “ Air cylinder . . 432
“ “ Air valves and strainer . 433
“ “ New York Duplex . . 434-437
“ “ Automatic Oil Cup . . 437-440
Pump Governor, The Duplex . . . 439
“ “ “ “ Operation of . 440
“ “ “ “ Vent port in . 441
“ “ “ “ Adjusting . 442
Brake Valve, Engineers’ — Principle of the 442
“ “ “ Style of L. Automatic 446
“ “ “ Release position . 446
“ “ “ Running position . 448
“ “ “ Holding position . 448
“ “ “ Lap position . . 449
“ “ “ Service position . 449
“ “ “ Emergency position . 450
Distributing Valve, principle of the . . 451
Distributing Valve, principle of the operation 454
Distributing Valve, principle of the operation, automatic 456
Broken Pipes 457
Main reservoir supply . . 457

    Application cylinder . . . . 457.
    Release pipe 459
    Brake cylinder pipe 459
    Brake pipe branch 459
    Feed valve pipe. 459
    Equalizing reservoir pipe . . 460
    Top governor pipe . . . 460
    Diaphragm chamber pipe . . 460
    Maximum governor pipe . . 460
    Brake pipe 460
    Reducing valve pipe . . . 461
    Signal pipe 461
Distributing Valves and Road Defects . 461
    Loss of main reservoir pressure 462
    Brakes set too hard . . . 463
    Brake will not apply on the engine during service application . 461
    Brakes will not apply doubeheading 464
    Handling dead engines . . 464
New York L. T. Equipment, operation of 466
" " " Full release . 470
" " " Charging position 470
Triple Valve, The Type K . . . 471
" " " " " Quick service 471
" " " " " Advantages of 474
" " " " " Manipulation 475
" " " " " Names of parts 477
Train Handling Freight Service . . 477
" " and piston travel . . 477
" " Time element in . . 481
" " Loads and empties . 481-485
" " Charging and testing . 482
" " Releasing long trains . 483

Train Handling Freight Service . . 477
" " Stopping trains . . 484
" " Backing off trains . 486
" " Releasing at low speed . 487
" " Releasing after a light reduction . . . 487
" " Cutting out brakes . 488
" " Doubleheading . . 488
Passenger Trains, Handling of . . 489
" " Testing of . . . 489
" " Stops with . . . 490
" " Stops with short . . 490
" " Overcharging . . 491
" " Running test . . 492
" " Taking cars en route . 494
" " Holding on down grades 495
Brakes applying from unknown cause . 495
Broken Brake Pipe 495
Emergency following a service application 496
Summary 496
Automatic and Straight Air Brake 498-499-500

GENERAL STUDY OF THE MODERN LOCOMOTIVE 501
Locomotives, Classification of 501
" Tractive, Power of 503
" " " " Compound . 504
Locomotive Boiler Calculations . . 505
" " Factor of safety . . 506
" " Seams 507
" " Staybolts, Strength of . 509
" " Staybolts, Safe pressure on 509

Locomotive Boiler Calculations . . 505
“ “ Firebox calculations . 510
“ “ Steam Dome calculations 510-513
“ “ Back head bracing . 513
“ “ Front tube sheet bracing 514
“ “ Shearing stress on rivets 514
“ “ Tension on plate net section 515
Steam saturated temperature formula . 515
Piston speed and revolutions per minute . 516
Train resistance and tonnage rating 517-518-519